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Final Report

September 1978

Contract DCPA01-76-C-0308
Work Unit 2313B

SRI Project 5591

Approved for Public Release; Distribution Unlimited

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CRISIS RELOCATION OF THE POPULATION AT RISK IN THE NEW YORK METROPOLITAN AREA

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By: Clark Henderson
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For:

Defense Civil Preparedness Agency
Washington, D.C. 20301

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The study treats the initial relocation of a risk population of 11.33 million persons and daily commuting by 0.91 million essential workers in the New York metropolitan area. A base case is described. Transportation resources are identified. Transportation capacity is estimated for air, water, rail, automobile, and bus transportation. Transportation operations and allocations of risk population groups to host areas are analyzed in trial solutions, and a base solution and move-table analysis are described. Relocation journeys are started by 95% of the population within 3.0 days and by the remainder at 3.3 days. Alternative

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cases treat changes in policies, conditions and constraints. Probable changes in duration of operations and transportation burdens are discussed. Substantial improvements over the base case appear possible.

PREFACE

SRI International has conducted a series of research studies on crisis relocation for the Defense Civil Preparedness Agency (DCPA). A recent report entitled "The Feasibility of Crisis Relocation in the Northeastern Corridor" (December 1976) dealt mainly with the problems of relocating populations at risk in major metropolitan areas in the northeastern United States and emphasized the severity of the relocation problem in New York City and adjacent suburbs. The research described in this report was undertaken at DCPA's request and deals with crisis relocation of the population at risk in the New York metropolitan area. An oral presentation of the research methods and results was prepared and delivered to audiences in the Washington, D. C. area; Albany, New York; and elsewhere. The text and exhibits for the briefing are presented in a separate annex to this report.

The DCPA was represented by Mr. George C. van den Berghe, the Contracting Officer's Technical Representative. Responsibility for conduct of the research was shared by SRI International's Transportation and Industrial Systems Center (Dr. Robert S. Ratner, Director) and Center for Resources and Environmental Systems Studies (Dr. Steven L. Brown, Director).

Mr. Clark Henderson was project leader and was responsible for the transportation analysis. Mr. Walmer E. Strope of the Center for Planning and Research, Inc. (formerly with SRI) was responsible for the allocation analysis. Dr. Masami Sakasita was responsible for highway route identification and highway capacity analyses. Ms. Hazel T. Ellis, Ms. Betty Neitzel, Ms. Marika Garskis, Mr. Ed Meko, and Ms. Edie Dorosin provided assistance.

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SUMMARY AND RECOMMENDATIONS

The problems of crisis relocation and of daily commuting by essential workers were analyzed for the population at risk in the New York metropolitan area and for populations of outlying risk areas in New York State. The Defense Civil Preparedness Agency (DCPA) supplied the populations at risk and the areas suitable for hosting.

Objectives

The goals stated by DCPA were to relocate all risk populations within three days at distances no greater than 200 miles. Satisfaction of these goals was not an absolute requirement, however. If necessary, operations could continue for a longer time and people would travel greater distances.

Problem Definition: Base Case

The duration of relocation operations and the distances of travel are influenced strongly by policies and conditions that have not yet been officially established. When such inputs were not available, assumptions were adopted by the analysts, after consultation with DCPA personnel. These assumptions were used to define and to solve in detail a single "base case." Alternative policy assumptions and conditions were then described in qualitative terms and evaluated in relation to the base solution.

The most important policy assumptions for the base case were:

- Boundaries of the New York Crisis Relocation Planning Area were drawn to include all but 5 New York counties plus four Pennsylvania counties.
- Hosting capacity was assumed to be 5 relocatees for each host area resident.
- The entire risk population was assumed to relocate during the main operation.
- Essential workers, comprising 8% of the population, were assumed to commute daily to key jobs. Essential workers and dependents (comprising another 12% of the population) were assumed to relocate to host areas chosen to ease commuting burdens.

- Households having access to an auto were assumed to relocate by auto (except in one area where a small group was airlifted to shorten commute times).
- Certain transportation resources, not otherwise slated for use, were borrowed from New Jersey and Pennsylvania.

Results of the Base Case Solution

Travel Modes

The 11.33 million persons at risk in the New York metropolitan area reside in 3.8 million households with an average of 3.1 persons each. About 6.5 million persons reside in households having access to an automobile. With one minor exception involving substitution of air travel, all of these people relocate via auto. About 4.8 million persons live in households without autos and relocate by air, water, rail, and bus.

The solution to the base case indicated that relocation could be accomplished as follows:

	Million	Percent
Air	1.22	10.74
Rail	1.58	13.52
Water	0.30	2.65
Bus	1.76	15.52
Auto	6.52	57.57
	11.33	100.00

The risk population includes about 906,000 essential workers, or 8% of the total. Commuting was by these modes:

	Thousand Million	Percent
Air	95.4	10.53
Rail	300.4	33.15
Auto (or bus)	510.5	56.33
	906.2	100.0

Relocation Times

In the base solution, 95% of the risk population started relocation journeys by the end of the third day. The remaining 5% relocated via auto and began their journeys by D + 3.3 days. The three-day goal was not achieved in the base case but could be achieved under several of the alternatives that were described. The alternatives were not analyzed in the detail needed to produce quantitative results.

Relocation Distances

The 200-mile goal for relocation distance was exceeded because of the lack of sufficient hosting capacity within that range. It is now clear that a more detailed goal statement for travel distances is needed because relocation burdens imposed by distance vary greatly among modes. For example, trips of 400 miles or more via air are easy on travelers, while 100-mile trips in trucks or freight cars will impose severe hardship on some. Trips of 150 miles in buses with small, hard seats (such as those used for urban transit and schools) will be exhausting for many travelers. Auto travel is relatively comfortable, however, the gasoline tanks of most autos limit the distances that can be traveled. Trips longer than 250 miles will require refueling some autos.

Average trips via autos were about 200 miles. However, 20% of the relocation trips were longer than 250 miles, and some were almost 400 miles. Shorter travel distances would be achieved under some alternatives, but the 200-mile goal cannot be achieved. Beneficial changes increased either road capacity to hosting areas in the south-central counties of New York or the hosting capacity in other areas east and south of the New York metropolitan area. Conversely, changes that reduced close-in hosting capacity increased travel distances via auto.

Average distances via air and rail were not estimated but would be tolerable except perhaps on one rail route where freight trains are used. Trucks were not used for long journeys. In the base case, bus trips averaged about 100 miles--a distance considered likely to be tolerable.

Alternative Cases

Eleven alternative cases were described and discussed. These cases represent assumed changes in policies, planning area boundaries, planning factors, and other matters. Examples are:

- Redraw planning area boundaries to regain one New York country from the New England planning area.
- Increase the hosting ratio to 6 to 1 in selected counties.
- Change hosting criteria or provide shelters in close-in areas now deemed subject to fallout risk. Host some New York residents living in such areas in New Jersey.
- Shift relocation mode of some families from auto to bus.
- Borrow roads from New Jersey.
- Increase average auto loads 10% by requiring families to carry other people in family autos.
- Relocate only 90% of the risk population during the main operation.

Several of the above changes were sufficiently effective to reduce the duration of operations to three days. Two or more such changes, used in combination, would provide a margin of safety and thereby lower the stress on the relocation operation. Some alternatives shorten travel distances, but none approaches the 200-mile goal.

Conclusions

Transportation Resources

Transportation resources for crisis relocation are relatively abundant and afford planners some freedom of choice. Vehicles of all types but one--intercity rail passenger cars--were available in greater quantities than needed. Generally, capacities were limited by transportation facilities rather than vehicles. For example, the base solution used all highway route capacity, all railroad route capacity to host areas, and all commercial airport capacity in host areas.

Planning and Management

Planning and management are critically important to the successful conduct of crisis relocation operations. Some problems of planning and

management were explored in this research. No unyielding obstacles to success were discovered, but many important and difficult problems remain to be worked out. Advanced preparation and small investments in facilities and equipment will be required. Transportation management is critically dependant on communications.

Public Response

The success of crisis relocation operations also depends on generally constructive and cooperative public responses. Travelers must follow instructions and schedules. Changes may occur hour by hour, and travelers must adjust their behavior accordingly.

Recommendations

Detailed analyses of alternative cases should be made using the move table transportation and allocation analysis techniques developed in this research. The qualitative treatment of the alternatives presented in this report is not adequate for evaluations and should be supplemented. Various alternatives of interest to policymakers, planners, and transportation analysts should be described, analyzed in detail, and evaluated as inputs to official plans.

Formal methods and procedures for crisis relocation analyses should be developed and documented. Computer programs and labor-saving techniques should be developed. Improved methods will benefit policymakers and planners and can be used by the DCPA to test the adequacy of local and state plans.

Surveys should be made of all risk areas in the United States having large risk populations of, say, 2 million or more. The surveys should assess relative difficulties and special problems of large areas. Those areas found to face especially difficult problems should be studied by teams of specialists as well as by local and state planners.

I INTRODUCTION

Background

A national crisis relocation policy is one option for reducing the vulnerability of the population of the United States to the threat of nuclear attack and is under active development and prototype testing by the Defense Civil Preparedness Agency (DCPA). At least part of the justification for this development is the fact that crisis relocation has emerged as a basic civil defense option in the Soviet Union. Plans for evacuation of U.S. cities in response to evacuation of Soviet cities in a crisis may be regarded as a stabilizing influence contributing to crisis resolution. It is also a measure that has the potential of saving tens of millions of lives, should a crisis escalate to nuclear war. To match the pace attributed to Soviet capabilities, U.S. relocations would have to be accomplished within a period of three days.

The Feasibility Study

Research on crisis relocation problems and solutions in the United States has been in progress for some time. At the outset, many responsible civil defense professionals were dubious of the practicality of several key aspects of crisis relocation, especially in the highly urbanized northeastern states.

The problems of relocating the risk populations of this region were examined and described in a feasibility study entitled "The Feasibility of Crisis Relocation in the Northeastern Corridor."* That study examined the relocation of risk populations of various sizes. It was shown that risk areas having populations of one million or fewer persons

* W. E. Strope, C. D. Henderson, and C. T. Rainey, "The Feasibility of Crisis Relocation in the Northeast Corridor," Stanford Research Institute, Menlo Park, California (December 1976).

generally have ample transportation resources and will be able to relocate without severe difficulty in three days or less. Although risk areas having larger populations face more difficult problems and must plan accordingly, research to date indicates that all northeastern cities, except New York, can relocate in three days.

The New York metropolitan area includes New York City, Nassau County, and parts of Suffolk, Rockland, and Westchester Counties. It has the largest risk population in the northeast--11.33 million persons--and faces especially difficult relocation problems. In the trial solutions made in the feasibility study it appeared that relocation operations in the New York metropolitan area would continue through most of the fourth day.

<u>Purpose</u>

The main purpose of this research is to find ways and means to accomplish relocation of the New York risk population within three days or within the shortest possible extension of time beyond three days. Initial relocation of the risk population to host areas and transporting essential workers between host areas and job sites in risk areas are the most severe challenges. Delivering food, fuel, and other supplies to host areas and returning the risk population to their homes are important but not critical problems and are not addressed in this research.

<u>Scope</u>

The DCPA contracted with SRI International (formerly Stanford Research Institute) to conduct a study entitled "Crisis Relocation of Population at Risk in the New York Metropolitan Area." The following language is an excerpt from the contract:

> F.1. STATEMENT OF WORK - NEW YORK EVACUATION STUDY
>
> A. <u>GENERAL</u>. - The Contractor, in cooperation and consultation with the Government, shall furnish the necessary personnel, facilities, materials, and such other services as may be required to analyze the problems of crisis relocation of populations at risk in the New York Metropolitan Area.

B. SPECIFIC WORK AND SERVICES. - The Contractor shall perform specific work and services as follows:

(1) Make an allocation permitting the movement out of the risk areas and into the host areas in a period not to exceed 72 hours while the maximum distance to be traveled by relocatees should not be more than 200 miles.

(2) Explore solutions to the problems of limited ownership of automobiles in New York and of the insufficient capacity of outbound highway lanes.

(3) Reallocate the risk area population to host areas after a more specific and accurate survey of resources such as lodging, shelter and vital supplies in the host areas thereby permitting a desired depression of the hosting factors.

The work has been accomplished in a series of stages as follows:

- Prepare an initial description of the relocation problem.
- Analyze transportation resources to identify their availability and capacities.
- Conduct trial solutions to the allocation and transportation problems and assess the effectiveness of each solution in terms of the time required to relocate the risk population.
- Revise the allocations of the risk population to host areas, revise the boundaries of the host area developed in the feasibility study, and adjust the transportation solutions to the extent necessary to:
  - Shorten the time for relocation
  - Achieve better balance and more effective use of transportation resources
  - Explore effects of changes in the relocation rules or policies upon time required for relocation.
- Summarize results.

In September 1977 the contract was amended to add paragraph B(4), as follows:

(4) <u>Dissemination of Crisis Relocation Findings in the North East Corridor</u>

(a) Provide data, results and conclusions of the N.E. corridor and New York research activity to the Systems Planning Corporation group and cooperate in conducting the special Study of Civil Defense for the Secretary of Defense and the President.

(b) Prepare a series of briefings on the data, research, calculations and findings of the N.E. Corridor and New York Metropolitan Area study. These briefings are to be geared to the professional level of the various audiences for which they will be prepared including industry representatives, airlines, railroads, motorbuses, government officials at all levels, and service organizations of various types having a prospective role in crisis relocation or other NCP measures. Special emphasis should be placed on the interests, responsibilities and sensitivities or idiosyncrasies of specific audiences or groups.

(c) Prepare a thorough and all encompassing briefing to be delivered at DCPA headquarters at a time suitable to the government and prior to the briefings in (b) above which will be scheduled in New York and other cities of the Northeast at DCPA's discretion.

(d) Prepare a report describing all the activities performed under (a), (b), and (c) above, giving textually the content of the briefings, commenting on audiences reception and recommending possible future actions for the consideration of DCPA.

The additional work has been accomplished by these measures:

- Participate in the special Study of Civil Defense included attendance at three 2-day workshop meetings; delivery of an oral presentation on crisis relocation in the northeastern states and in New York; *a special* analysis to estimate, for the nation, the cumulative number of people who can be relocated from all risk areas versus the elapsed time from the start of operations; and contributions of information and views in workshop discussions.

- Charts and notes were prepared for a series of briefings geared to the interests and responsibilities of professional personnel in various transportation modes and in civil defense.

- A comprehensive version of the briefing was delivered at DCPA headquarters in March 1978. A shortened version of the briefing was given later in the same month for regional and state civil defense planners and officials in Albany, New York. Valuable comments and suggestions were received at these briefings.

- A briefing was given to a workship at La Jolla Institute in June 1978.

- A written version of the briefing charts and text was prepared and submitted to DCPA as a separate annex to this report.

Audience reception of the oral presentations has been generally favorable. Questions and suggestions by members of the two DCPA and state audiences have led to changes in the presentation, which are

noted in the text. Inputs from state planners led to one substantial correction involving a factual error in the specification of a highway route. The specifications of three highway routes and the mode of operation on one route were revised to accommodate the correction. The change was accomplished without loss of capacity and without effect on the central analytical results of the study, as portrayed in the base solution.

Conclusions and recommendations for future actions are presented in the Summary and Recommendations.

II PROBLEM DEFINITION

Assumptions and Data Inputs

The feasibility study was the point of departure for this research and provided many of the policy assumptions and data inputs needed for problem definition. As in the feasibility study, the analysts in this project found it necessary to adopt assumptions in lieu of official policies not yet established. Important information regarding the risk population, hosting capacities, and other matters have been taken from the feasibility study. This section discusses the information that defines the crisis relocation problem for the New York metropolitan area. Attention is called to certain information that may be improved upon later by persons responsible for preparing actual crisis relocation plans.

Focus on Relocation and Commuting

Transportaion problems associated with crisis relocation for the population at risk in the New York metropolitan area were defined and analyzed, in preliminary fashion, in the feasibility study. Transportation services will be required for initial relocation, commuting trips by essential workers, delivery of supplies, and return of the risk population after resolution of the conflict. Based on the feasibility study it is clear that initial relocation and commuting are, by far, the most difficult problems in the New York metropolitan area. Although planners concerned with actual operations will need to cover all four transportation services, this research treats only relocation and commuting.

Three-Day Goal

A three-day period for initial relocation is the goal but not as a time limit on the duration of operations. Consequently, movements are assumed to continue beyond the end of the third day, if necessary, until relocation of the risk population has been accomplished.

Base Solution and Alternatives

The best way to use limited transportation resources was not clear at the outset of this study. Consequently, the study incorporated a series of trial solutions aimed at optimum exploitation of available resources. The study culminates with a "base solution," which is the best solution attained under stated criteria. Several alternative solutions for revised criteria and assumptions are also presented.

In the trials leading to the base solution, attention was first given to estimates of the capacity of all nonhighway modes--air, rail, and water. It was assumed that those modes will be used mainly by carless persons but may also be used to ease commuting trips by some essential workers and dependents who have access to "first" autos.* Highway capacity on selected routes was then allocated to large vehicles until the production rate reached the level needed to move the remaining carless risk population in three days. Care was taken to see that the supply of large vehicles was not exhausted. In the last stage, all of the highway capacity not used by large vehicles was allocated to first autos and the operation was continued until all persons in households with autos had been moved.

If three days or less had been required to move all first autos, the base solution would have been acceptable in all respects. However, more than three days was required and a series of new trials aimed at alternative solutions were planned and carried out. One alternative gave large vehicles--buses and trucks--priority use of certain highways and required persons who have access to a first auto to travel by bus, truck, or other modes. Another alternative assumes a change in hosting criteria in areas near the risk area. The analytical procedure and the base solution results are presented in Section VII. Alternative solutions are presented in Section VIII.

*A "first" auto is the vehicle most suitable for relocation travel in an occupied dwelling unit having access to one or more autos.

Population at Risk

In the feasibility study the population at risk in the New York metropolitan area was estimated to be 11,328,400 persons, based on 1970 Census data. The population at risk includes all residents of New York City, which includes New York County (Manhattan); Richmond County (Staten Island); Kings County (Brooklyn); the Bronx, and Queens. It also includes all residents of Nassau County and parts of the population of Suffolk, Westchester, and Rockland Counties. (See Table 1, lines 1 and 2, for details.)

The populations at risk in other areas in New York State have been taken into account in this analysis. In Section VII provisions have been made for their relocation.

Entire Risk Population Relocates

In this study, as in the feasibility study, it is assumed that the entire risk population will be relocated. No reduction was made to allow for spontaneous relocations that may occur during the crisis buildup or for persons who may refuse to relocate. However, in an actual operation the fraction of the risk population to be relocated may be as low as 80%.

It would be desirable to estimate the number of people who will not relocate and take advantage of the knowledge in planning transportation for actual relocations. For example, a 10% reduction in numbers of persons to be relocated would shorten relocation time significantly. No procedure was found to make such estimates. However, procedures for monitoring behavior during the relocation operation were suggested in the feasibility study (p. 103).

Changes in Estimates of Population at Risk

The determination of the areas and populations at risk involves a complex analytical process and a number of judgmental inputs. Thus, boundaries of risk areas and estimates of populations at risk used in this research may be subject to revision in actual planning operations. Downward revisions are desirable, from the transportation viewpoint, to reduce the burdens of relocation and commuting.

Table 1

SUMMARY OF INPUT DATA: POPULATION AND ACCESS TO FIRST AUTOS

	Line	Source	Bronx	Kings	Nassau	N.Y.	Queens	Rich-mond	Rock-land	Suffolk	West-chester	Total
Population												
County	1	NOI*	1,471.7	2,602.0	1,428.8*	1,539.2	1,987.2	295.4	229.9	1,127.0*	894.4	11,575.6
At risk	2	SRI	1,471.7	2,602.0	1,428.8	1,539.2	1,987.2	295.4	191.9	1,061.4	750.9	11,328.4
Percentage at risk	3	Line 2 ÷ 1	100.0	100.0	100.0	100.0	100.0	100.0	83.5	94.2	84.0	97.9
Essential workers	4	8% of line 2	117.74	208.16	114.30	123.14	158.98	23.63	15.35	84.91	60.07	906.27
Essential workers and dependents	5	20% of line 2	294.34	520.40	285.76	307.84	397.44	59.08	38.38	212.28	150.18	2,265.68
Occupied Housing Units												
County	6	Col. 85	497.2	876.1	401.1	687.3	690.1	86.2	60.4	295.6	282.6	3,876.5
At risk	7	Line 3x6	497.2	876.1	401.1	687.3	690.1	86.2	50.4	278.5	237.4	3,804.3
Average Persons Per Unit	8	Col. 86	2.9	2.9	3.5	2.2	2.8	3.4	3.8	3.8	3.1	3.1
Percentage with First Autos	9	Col. 101	37.6	41.5	91.7	21.5	63.6	80.1	90.8	93.1	82.6	54.5
Access to First Autos												
Number of housing units at risk	10	Line 7x9	186.9	363.6	367.8	147.8	438.9	69.0	45.8	259.3	196.1	2,075.2
Number of persons at risk	11	Line 10x8	542.0	1,054.4	1,287.3	325.2	1,228.9	234.6	174.0	985.3	607.9	6,439.6
No Access to First Autos												
Number of persons at risk	12	Line 2-11	929.7	1,547.6	141.5	1,214.0	758.3	60.8	17.9	76.1	143.0	4,888.9

Source: U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1972, Table 2.
U.S. Department of Commerce, Bureau of the Census, Number of Inhabitants.

*Corrected Census number.

Hosting Ratios and Areas

The hosting ratio assumed for this study, as in the feasibility study, is five relocatees for every host area resident and is assumed to be uniform in all host areas utilized--that is, a host area is assumed to accommodate a risk population five times its own population. (Analysts dealing with actual relocation plans may find it necessary or desirable to use other hosting ratios. For example, use of higher ratios in areas near the risk area will tend to shorten travel distances.) Under the 5-to-1 criterion, New York State has more than enough hosting capacity for all risk populations in the state.

Planning Area Boundaries

In this research, most of the risk population of New York State is assumed to be hosted within the state. However, five counties in northeastern New York State are assumed to be used to host risk populations from New England. This measure is needed to preserve the 5-to-1 hosting ratio for the New England population. Also four Pennsylvania counties are assumed to be used to host part of the risk population to the New York metropolitan area. This measure is adopted to shorten travel distances. There is unused hosting capacity in western New York State, but travel distance via surface modes are excessive. Boundaries of the planning area are shown in Figure 1.

Possible use of parts of two New Jersey counties for hosting the New York risk population is treated in Section VIII.

Hosting Essential Workers

Certain services in the risk area are essential and will have to be continued throughout the crisis. Therefore, essential workers will relocate and then commute between host areas and job sites in the risk area. It follows that essential workers and their dependents will have to be assigned to host areas that are accessible to the risk area to minimize the daily burden of commute trips and to equalize commuting burdens as nearly as possible.

FIGURE 1 NEW YORK CRISIS RELOCATION PLANNING AREA

In this study, as in the feasibility study, it was assumed that 8% of the risk population are essential workers and 12% are dependents of essential workers. In the solution treated in this report, about 2,266,000 persons are relocated to host areas suitable for commuting to job sites, and about 906,000 persons commute daily to job sites (see Table 1).

These estimates of essential workers and dependents were not based on detailed study and may be substantially higher than actual requirements in the New York risk area. In actual planning, it will usually be desirable to hold down the number of commuters so as to reduce the burdens of commuter transportation.

Phasing Relocation of Essential Workers

The start of commuting travel was postponed until the end of the relocation period because some transportation resources must be used for both relocation and commuting. To accomplish this, essential workers having jobs that can be interrupted for periods of up to three days and their dependents would be phased in with the relocation of the general population. These workers would remain idle in the host area until full-scale commuting can begin. Workers having jobs that cannot be interrupted, together with their dependents, would relocate at or near the end of the relocation period. Regular commuting by the entire essential work force would begin immediately after the end of the relocation period.

Scale of Commuter Traffic

It is assumed that work shifts can be as long as 12 hours and that working hours can be staggered round the clock to produce a level load on the transportation system. If done in this way the burdens of providing commuter service for 8% of the risk population in the New York metropolitan area appear moderate. For example, hourly flow rates in each direction would be 38,000 persons per hour. In Section VII it is shown that commuter railroads and aircraft can provide much of this service.

Buses and subways will be used for feeder and distributor service. Buses will be used for some commute trips. Air travel will be used by some essential workers to avoid the longest and most time-consuming trips by surface modes (e.g., to Suffolk county). Private automobiles will be used where necessary.

Equity in Relocating the General Population

The allocation of the general population from risk counties to host counties was done under a principle of equity or fairness--that is, the relocation travel burdens imposed upon the residents of all risk counties should be as near equal as can be arranged.

There are practical obstacles to the attainment of the equity goal when several transportation modes are used. For example, people relocated via air will probably enjoy faster and easier trips than those relocated by any other mode. People relocated by trucks and rail freight cars will experience slow, and uncomfortable trips. However, a large fraction of the population will move by first auto, and a technique has been developed to achieve equitable allocations for persons in this group. This technique is called the "20 percent slice" and is described in Section VII.

Transportation

Special Routes

Special highway routes can be composed or synthesized from segments of available highways, and arrangements for highway marking can be made in advance. Special routes can also be composed for each nonhighway mode. Routes for nonhighway modes are dictated largely by the locations of existing facilities. Air routes will link relatively small numbers of airports in the risk and host areas. The Hudson River is the principal water route, and existing port facilities will have to be adapted to passenger service. Rail routes will have terminals at existing stations and yards in the risk area and will make deliveries to stations or expedient unloading points along rail routes in host counties.

Certain highway, air, and rail special routes are suitable for commuting as well as for relocation traffic.

Preparations

It is assumed that the needs of crisis relocation operations will be recognized in civilian transportation programs and that plans and preparations for crisis relocation will be made in advance. Crisis relocation operations will be given first priority for all public and private transportation resources except those needed for critically important military missions. Major investments in transportation equipment and facilities for crisis relocation are not expected although certain highway bottlenecks identified in Section VI should be eliminated if possible.

Regulation of Traffic Flows

It has been assumed that traffic flows via all modes and on all routes can be regulated within about ± 10% of planned flow rates. This degree of control is necessary if production targets are to be achieved. If traffic flow exceeds the planned upper limit, there is a high risk that congestion will occur and flow will drop far below standard. If traffic flows fall below the planned rate for any substantial period of time, some production will be lost beyond hope of recovery. Regulations of movements must begin near the homes of people to be relocated and must be maintained throughout the system.

Planners will subdivide the entire risk area into districts of, say, 50,000 persons, and persons in each district will be scheduled to depart during one or more relatively short intervals of time. At any moment during the relocation operation a small number of districts will be initiating relocation movements, but most will be static. Persons in each district will be directed to initiate relocation by going to a specific collection point (e.g., a school) or entry point (e.g., a subway station or a freeway ramp) during a certain time in interval. These facilities will be opened and closed to relocation traffic in accordance

with the schedule and a large fraction of the collection and entry points will be closed at any moment in time. This procedure will provide the first stage of traffic regulation. Thereafter, each route and transfer point will require constant supervision.

Nonessential Travel

During the crisis, and especially during the relocation phase, nonessential travel will be severly curtailed. This is necessary to achieve maximum capacity, to conserve fuel and other resources, to avoid needless burdens on personnel and equipment required for regulating traffic and servicing vehicles, and to aid police in maintaining order and protecting property.

Addressing Relocation Groups

A scheme of addressing relocation groups is needed to subdivide the risk area into small districts and to further subdivide the risk population of each district into small relocation groups. This scheme will allow for the preparation of printed instructions and the radio broadcasting of changes in plans and revisions of schedules as needed. The objective should be to address instructions and messages to a few hundred people at a time.

A scheme for addressing small groups has been envisioned. It would use postal zone (ZIP) codes, two digits of the auto license number, and the birth date(day of month) of individuals. The scheme described below is illustrated with data from Nassau County and Manhattan. The first element of the address would be a ZIP code number. In Nassau County the average postal zone has about 75,000 persons and about 21,400 occupied housing units. Automobile ownership is high at about 19,600 first autos.* By using two digits of a license number, as the second element, controllers can broadcast instructions to the population having access to a

* Source: Postal zone maps and U.S. Census of Population, 1970.

first auto. In Nassau County that would be about 200 travel parties and about 700 people. In Manhattan postal zones in residential areas average about 37,000 persons and about 17,000 occupied dwelling units.* There are only about 3,600 first autos in the average postal zone, and controllers can address as few as 40 travel parties using this scheme.

The average Manhattan postal zone has about 13,000 occupied dwelling units without autos including about 29,000 carless persons. Separate instructions addressed by using a ZIP code and the birth date of the head of household or travel party would apply to about 1/30 of the carless people in an area. In Manhattan that would average about 430 dwelling units and about 950 persons.

This scheme of addressing relocation groups subdivides the area and the population sufficiently for transportation planning and appears to be simple and practical. Planners of actual operations will need to develop and use this or some other scheme.

Highway Modes

The feasibility study established the fact that highways and highway vehicles are the most valuable resources for crisis relocation but that highway capacity on routes leading from New York City to host areas to the north and west are in short supply. Private automobiles are the most attractive highway vehicles for most travelers. However, large vehicles--buses and trucks--make more productive use of highways.

Large Vehicles vs Autos

It is assumed that passengers will be transported in buses to the extent possible and especially for long trips. Trucks will be used to the extent necessarv. The use of autos and large vehicles can be adjusted to achieve needed levels of productivity. In one alternative

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*Source: Postal zone maps and U.S. Census of Population, 1970.

solution it was assumed that some persons with first autos are denied access to highways in favor of large vehicles. This means that some people would be required to leave an auto at home and travel either in a bus or truck.

First Autos

Persons in housing units having access to one or more automobiles are expected to use the most suitable vehicle for relocation travel--up to limits imposed by highway capacity. In the feasibility study it was estimated that 2,075,200 first autos exist in the risk area (see Table 1, line 8). It is assumed that persons who reside together will relocate together. The average number of persons per dwelling unit ranges from a low of 2.2 in Manhattan to a high of 3.8 in Suffolk and Rockland Counties. (See Table 1, line 4.) The average for the entire area is about 3.1 persons per unit. Variation among counties has not been treated in this study but should be treated in actual planning. In the entire risk area about 6,439,600 persons (56.8%) have access to first autos and about 4,888,900 persons (43.2%) are carless.

In both the base and alternative solutions, it has been assumed that carless persons will not use borrowed or rented autos. If the number of autos used exceeds the number of first autos, relocation via auto will require more time than shown in the base solution, and the duration of relocation operations in large vehicles and nonauto modes will be shorter.

Auto Occupancy

In the base solution it has been assumed that the automobile loads will average 3.1 occupants plus luggage. This is significantly lower than the average loads of 3.3 persons and luggage observed in autos used for vacation travel.* It would be desirable to increase average

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* U.S. Department of Transportation, "National Personal Transportation Study: Automobile Occupancy," Report 1, Federal Highway Administration, Washington, D.C. (April 1972).

auto loads. For example, an increase of 0.1 persons per auto would shorten the duration of relocation in the base solution by about 3% or about 0.1 days.

It is also necessary to avoid having average occupancy fall below the planned level since each loss of 0.1 persons per auto will lengthen the operation by 0.1 days. Because of the importance of maintaining planned levels of auto occupancy, planners will need to monitor traffic streams entering relocation routes and compute running averages of vehicle occupancy and take corrective action when necessary. For example, if the average is observed to fall below target, drivers of vehicles with one person (or perhaps two persons) would be denied access to the relocation route. Those drivers would have several options--they could form a larger travel party by car pooling or by transporting one or more carless persons, or they could wait until the end of the relocation operation when highway capacity will be abundant.

Nonhighway Modes

The feasibility study indicated that nonhighway modes must be exploited to the fullest extent possible because highway capacity is limited. Air and rail transportation modes were treated in the feasibility study and are used to an even greater extent in the base and alternative solutions. In addition, water transportation is used for the first time in the present study.

Round Trips Versus One-Way Travel

Large-capacity vehicles of all kinds can be used in two operating patterns--one-way outbound or round trips. Circumstances will determine which pattern is most appropriate for each mode and route. Generally, it is expected that highly productive vehicles, such as commercial aircraft, buses, and passenger trains, will make round trips. Vehicles that are less productive or more abundant, such as small and intermediate trucks, may be used either way. First autos, locomotive, and box cars are relatively abundant resources and will generally make only one loaded trip.

Local Travel: Collection and Distribution

Travelers in first autos will travel from home to host destination without having to change vehicles, but persons making the main relocation journey via air, rail, water, and highway (bus or truck) will need collection service, from home to loading point, in the risk area; and distribution service, from unloading point to final destinations, in host areas. This research has concentrated on resources for main relocation journeys because resources for local travel appear to be relatively abundant.

Distribution of travelers from unloading points to congregate care facilities in host areas will be made via highway using school buses, buses, trucks and private automobiles. The magnitude of the distribution problem appears to be small in relation to available resources. The most severe single problem is likely to be the distribution of travelers from the Buffalo and Niagara airports. An analysis indicates that this distribution can be accomplished using only a small part of local resources.

In the risk area, collection services will be provided in many different ways depending on the transportation mode and loading point used for the main journey. Some travelers will use several modes in series to reach the loading point. Some likely sequences are as follows:

- Leave home, walk to school, and ride bus to host area.
- Leave home, walk to subway, ride subway to Queens, ride truck to airport, and ride aircraft to host area.
- Leave home, ride bus to Grand Central Terminal, ride Conrail to North White Plains (in risk area), ride bus to host area.
- Leave home, walk to subway, ride subway to World Trade Center, ride Path subway to Hoboken, ride Conrail to host area.

The main loading points will be commercial airports, rail passenger stations and rail freight yards, and waterfront facilities. It is expected that collection services will be performed by existing transportation systems under suitably revised operating procedures and by trucks pressed into passenger service. The Long Island Rail Road

commuter trains and the New York City Transit Authority (NYCTA) and Port Authority Trans-Hudson subway trains serve almost all parts of the risk area and will be the backbone of the collection system. Chauffeured vehicles, mainly intermediate trucks, will operate on special routes from residential areas to subway stations and from subway stations to airports, docks, and rail yards. Automobiles must not be used for collection services because access road and parking capacity is limited, and roads would quickly become clogged.

The scale of collection services will be small in comparison to normal weekday travel in New York City. The largest number of people will be collected at Grand Central Terminal. It has direct connection with three subway lines plus street modes and should be adequate service. A more difficult problem is expected to occur at John F. Kennedy International Airport (JFK) where both subways and trucks must be used. This problem is discussed in Section III. It appears that the subways near JFK have sufficient capacity to serve the flow of travelers. However, subway stations are not located at the airport. Passenger service via roads will be needed between subway stations and the airport. It is assumed that intermediate-sized trucks will be used for local collection services, to the extent needed, to free buses and large trucks for long-haul services. The inventory of intermediate-sized trucks appears to be far greater than needed for collection services.

III AIR TRANSPORTATION

In the base solution it was estimated that 273 commercial aircraft operating between 7 risk area airports and 14 host area airports would relocate 1,216,080 persons during a three-day period and would provide round trip daily commute service for 95,400 essential workers. Special air route characteristics and production are summarized in Table 14, Section VII.

Aircraft Types and Priorities

Three types of passenger aircraft are potentially useable in crisis relocations: military; general aviation, including air taxi, corporate, and private; and commercial air carrier.

Military aircraft were not analyzed because it was assumed that military missions would have first priority for their use. Planners may need to make one exception to that assumption. Military cargo aircraft are well suited for movement of large and heavy items of special ground equipment that will be needed at host airports where the commercial aircraft models served will differ from normal service and traffic volumes will be greatly increased. Commercial cargo aircraft will be able to perform part of that service.

General aviation aircraft were not analyzed, primarily because of the complexity of the problem of marshalling and managing many aircraft that vary greatly in size and performance, and because of the possibility that general aviation traffic would interfere with movement of larger and more productive commercial aircraft. In developing official plans for crisis relocation it may be appropriate to include general aviation, and there is a mechanism for doing so. General aviation aircraft are subject to mobilization under the State and Regional Defense Airlift (SARDA) program administered by the Federal Aviation Administration (FAA).

The general aviation fleet includes some large aircraft that might be used on the special air routes described in this section.

Commercial air carrier aircraft availability for utilization in a national emergency is assessed each year by the Civil Aeronautics Board (CAB).* One group of commercial aircraft comprises the Civil Reserve Air Fleet (CRAF). In a national emergency these aircraft are expected to be withdrawn from civil service for military use. The remaining aircraft comprise the War Air Service Program (WASP) fleet. In a national emergency these aircraft are to be used, under CAB plans, for the satisfaction of essential airlift requirements. In the present study it is assumed that the most essential function for these aircraft during a crisis relocation will be the relocation of populations at risk in a few large cities, including New York, where relocation problems will be especially severe.

Special Air Routes

The special air routes for crisis relocation airlift will have characteristics similar to the Eastern Airlines shuttle route that links LaGuardia with Boston and Washington and the discipline of the Berlin airlift. Each route has a base airport in the risk area (e.g., LaGuardia) and a delivery airport in the host area (e.g., Elmira). In the base solution 18 special air routes were employed.

Augmenting Airlift Resources

The capacity of an emergency airlift will depend upon availability of the following resources:

- Air traffic controllers.
- Aircraft and flight crews.

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*Civil Aeronautics Board, "War Air Service Program (WASP) Resource Report," Washington, D.C. (1976).

- Risk area airports, ground equipment, personnel, spare parts, and fuel.
- Host area airports, ground equipment, and personnel.
- Local ground transportation.

Transportation of passengers to and from airports in risk and host areas is discussed briefly in Section II. Examples are worked out in this section for one risk airport and two host airports.

Many of the essential resources--personnel and equipment--are present at the airports in the risk area. These resources can be augmented by deliveries from distant airports and by marshalling airlines not engaged in emergency operations in their home areas. Transportation of crews and equipment to the New York metropolitan area will be by air--mostly in the commercial aircraft that will be employed later in relocation service. Large items of equipment must be airlifted in civilian and military cargo aircraft.

A detailed estimate of fuel needs and supplies has not been made in the New York metropolitan area but the following data suggest that the fuel normally used in the New York metropolitan area in a three-day period would support the relocation airlift. It is assumed that non-emergency flying will cease. Airports in the area now account for about 16% of the jet fuel used by airlines at all U.S. airports.* The air fleet proposed for use in the emergency airlift is only about 14% of the WASP fleet. These figures suggest that fuel supplies should be adequate if the aircraft in emergency service consume fuel at rates substantially the same as in normal time. If consumption rates are higher than normal, it would be possible to draw down inventories at the air fields. It would also be possible to accelerate fuel deliveries from refineries which are nearby in New Jersey.

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* Air Transport Association of America, "United States Airline Industry Turbine Fuel Forecast: 1976-1980," Washington, D.C. (1976).

Minor airports in the risk area may lack fuel storage and handling facilities for the increased level of operations envisioned. If necessary, the aircraft using minor airports can land and refuel at one of the major airports once in every three or four round trips.

Availability and Capacity of WASP Aircraft

At the end of 1975 there were 1,945 commercial aircraft in the domestic and international WASP fleets. To simplify the analysis these aircraft have been grouped into seven classes according to seating capacity (see Table 2). Groups 5, 6, and 7 are assumed not to be exploited for crisis relocation. Group 7 is excluded because the aircraft have small seating capacities or are not in common service. Groups 5 and 6 have been excluded because their relatively low seating capacities and production rates make poor use of the limited airport capacity in the risk areas. (In practice, crisis relocation planners may find ways to use additional airports for which only Group 5 and 6 aircraft are suitable.)

Nominal capacities of groups 1 through 4 range from 90 (Group 4) to 340 (Group 1) seats. Actually, seating capacities vary somewhat within aircraft model numbers. The nominal capacity shown in Table 2 is the lowest number of seats listed in the WASP report rounded to a multiple of 10. Under loading alternative A, capacities are about 10% above the nominal capacity for each group. This increase recognizes the fact that 20% of the risk population are children age 12 or younger who can double up in seats. It is believed that this number of passengers could be carried while observing the normal requirement for individual seats and seat belts.

Loading alternative B would be achieved by waiving the seat belt requirement and carrying an additional 20% of the nominal capacity seated on the passenger cabin floor. This practice would have to be discontinued in periods of rough air. However, such periods would not usually make up a large fraction of a three-day period. In this report, loading alternative B has been used for relocation service. The nominal capacity has been used for commuting service.

Table 2

WASP AIRCRAFT

Aircraft Capacity Group*	Model	Number of Aircraft*	Nominal Seats*	Loading Alternatives† A	Loading Alternatives† B
1	B-747	20	340	375	440
		20			
2	DC-10	101			
	L-1011	77	230	255	300
		178			
3	B-707	188			
	DC-8	98	130	145	170
	B-727-200	379			
		665			
4	B-727-100	306			
	B-737-200	130	90	100	120
	DC-9-30	247			
		683			
	Subtotal	1,546			
5	BAC-1-11	41			
	DC-9-10	70	70	80	90
		111			
6	CV-580	93			
	CV-600	23	40	45	50
	F-27,227	28			
		144			
	Subtotal	255			
7	Other	144	--	--	--
	Total	1,945			

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* Source: WASP.

† Source: SRI.

Estimating Aircraft Productivity

The productivity of individual aircraft is measured in passengers delivered per day. Productivity depends on the number of passengers delivered per aircraft round trip, the number of hours required for each round trip, and the number of hours aircraft can be kept in the duty cycle each day, on the average.

To simplify the analysis, estimates have been made of the approximate times required for aircraft of each capacity group to make deliveries to airports 100, 200, and 300 miles from the New York metropolitan area and to return. Approximate distances between risk airports and groups of host airports have been used as follows:

Western area	300 statute miles
Central area and Albany	200 statute miles
Southeastern area	100 statute miles

Each duty cycle includes loading, scheduled travel time outbound, unloading, and scheduled travel time for return. Estimates have also been made of the average hourly productivity of individual aircraft while in the duty cycle (see Tables 3 and 4). It is of course recognized that aircraft cannot remain in the duty cycle 24 hours each day; some time must be allowed for maintenance and service. It is also likely that operations will be interrupted occasionally by weather, accidents, and the like. It is assumed here that each aircraft will be in the duty cycle 20 hours per day. If other assumptions are used in developing official plans, different numbers of aircraft will be required but airlift productivity will not be reduced. For example, if one assumes 15 hours per day in the duty cycle, the number of aircraft required to maintain the productivity used in the base and alternative solutions would be increased by one third.

Risk Area Airports

Airports used by commercial air carriers are best suited as bases for an emergency airlift, but primary, all-weather airports are also assumed to be useable. Six all-weather airports, three commercial and

Table 3

AIRCRAFT SCHEDULE FACTORS

	Aircraft Capacity Group					
	1	2	3	4	5	6
	Factors					
Time at loading gate (min)	50	40	25	20	20	15
Schedule time outbound, gate to gate (min)						
100 miles	30	30	30	30	30	40
200 miles	45	45	45	45	45	65
300 miles	60	60	60	60	60	90
Time at unloading gate (min)	50	40	25	20	20	15
Schedule time return, gate to gate (min)						
100 miles	30	30	30	30	30	40
200 miles	45	45	45	45	45	65
300 miles	60	60	60	60	60	90
Total cycle time (min)						
100 miles	160	140	110	100	100	110
200 miles	190	170	140	130	130	160
300 miles	220	200	170	160	160	210
Total cycle times (hr)						
100 miles	2.67	2.33	1.83	1.67	1.67	1.83
200 miles	3.17	2.83	2.33	2.17	2.17	2.07
300 miles	3.67	3.33	2.83	2.67	2.67	3.50

Source: SRI

Table 4

AIRCRAFT PRODUCTIVITY IN RELOCATION SERVICE

	Aircraft Capacity Group					
	1	2	3	4	5	6
	Factors					
Passengers delivered per trip with Alternative B loading	400	300	170	120	90	50
Round trips per aircraft per day (20 hr in duty cycle)						
100 miles	7.5	8.5	10.9	12.0	12.0	10.9
200 miles	6.3	7.0	8.5	9.2	9.2	7.5
300 miles	5.4	6.0	7.0	7.5	7.5	5.7
Passengers delivered per aircraft per day (20 hr in duty cycle)						
100 miles	3300	2571	1854	1440	1080	545
200 miles	2778	2117	1457	1107	830	375
300 miles	2400	1800	1200	900	675	285

Source: SRI.

three primary in or near the New York risk area were used in the analysis. Two airports--one commercial and one primary--in New Jersey are assumed to be useable for relocation of the New York metropolitan risk population, if needed. Only one was used. These airports are listed in Table 5 together with indications of the largest aircraft capacity group now employed (or assumed to be employable) and the number of departures that are assumed to be possible each day.

In normal times the capacity of airports is measured in operations per hour (arrivals plus departures) and depends upon many factors. Procedures for estimating capacity have been established by the FAA.

Table 5

CAPACITY OF RISK AREA AIRPORTS

Airport and County Location	Aircraft Capacity Group	PHOCAP IFR Operations Per Hour*			Assumed Emergency Capacity (Departures Per Day)
		Arrivals	Departures	Total	
New York					
Commercial					
John F. Kennedy International, Queens	1	35.5	35.5	71	710
LaGuardia, Queens	2	28.0	28.0	56	560
Islip, Suffolk	3	35.0	35.0	70	150
Commercial Total					1,420
Primary-All Weather					
Peconic River, Suffolk	4†	31.5	31.5	63	150†
Westhampton, Suffolk	4†	30.5	30.5	61	150†
White Plains, Westchester	4†	32.0	32.0	65	150†
Primary All-Weather Total					450
New York Total					1,870
New Jersey					
Commercial					
Newark International, Essex	1	27.0	27.0	54	540
Primary					
Teterboro, Bergen	4†	62.5	62.5	65	150†
New Jersey Total					690
Total					2,560

*Arrivals and departures are operations.

†Assumed.

The most appropriate measure, for present purposes, is believed to be the "practical hourly capacity" (PHOCAP) under instrument flight rules (IFR). However, this measure is related to the size of aircraft employed and is likely to overstate the capacity of primary airports when used by commercial aircraft rather than by general aviation aircraft.

For convenience in crisis relocation analyses, capacity has been measured in terms of the number of aircraft departures per day. It is assumed that major commercial airports can operate at their practical hourly capacities under IFR for the equivalent of 20 hours per day. Capacity estimates and actual experience for three major commercial airports are compared in Table 6.

Table 6

AIRCRAFT DEPARTURES PER DAY AT THREE MAJOR COMMERCIAL AIRPORTS

	Assumed Emergency Capacity	Average Day in 1975*
John F. Kennedy International	710	215
LaGuardia	560	348
Newark International	540	172

*FAA, "Airport Activity Statistics" (1975).

It should be borne in mind that the commercial airports normally operate above their average rate in peak hours and below their average rate at night and at other slack times.

The other risk area airports are not developed and equipped to accommodate large numbers of commercial air carrier aircraft. Consequently, it has been assumed that such airports will dispatch only 150

aircraft per day even though their practical hourly capacities under IFR are about the same as the three major commercial airports.

Host Area Airports

Conditions at the host airports are expected to govern both the size of aircraft employed on each route and the frequency of flights. In host areas the airports now employed by commercial air carriers are the primary resources for an emergency airlift. Other airports are known to exist and may be suitable for use but have not been analyzed. This is an area that should be explored at greater depth by planners.

The host airports that are assumed to be used are shown in Figure 2 and listed by area in Table 7, together with capacity estimates. The aircraft capacity group(s) assumed for each airport is shown together with the aircraft capacity (Alternative B) and the assumed number of deliveries per day. Special air routes have been tailored to the needs of the base solution and are identified in Section VII.

Deliveries to all host airports total 405,360 persons per day or 1,216,080 persons during a three-day period. This is almost 11% of the risk population and almost five times as great as the airlift envisioned in the feasibility study.

Aircraft used for commuter services will not carry children. It is assumed that passengers are required to use seat belts; and consequently nominal seating capacities are used in commuter service. The estimated daily productivity of the airports used for commuting in the base solution is given in Table 8. Commuting productivity could be increased by utilizing other airports.

Aircraft Required

The estimated numbers of aircraft required for relocation service are shown in Table 7. Requirements are compared with the numbers available in the WASP fleet in Table 9. It is estimated that commuting services will require 33 aircraft of capacity group 2 and 65 aircraft of capacity group 4. Again, these requirements are small in comparison with available resources.

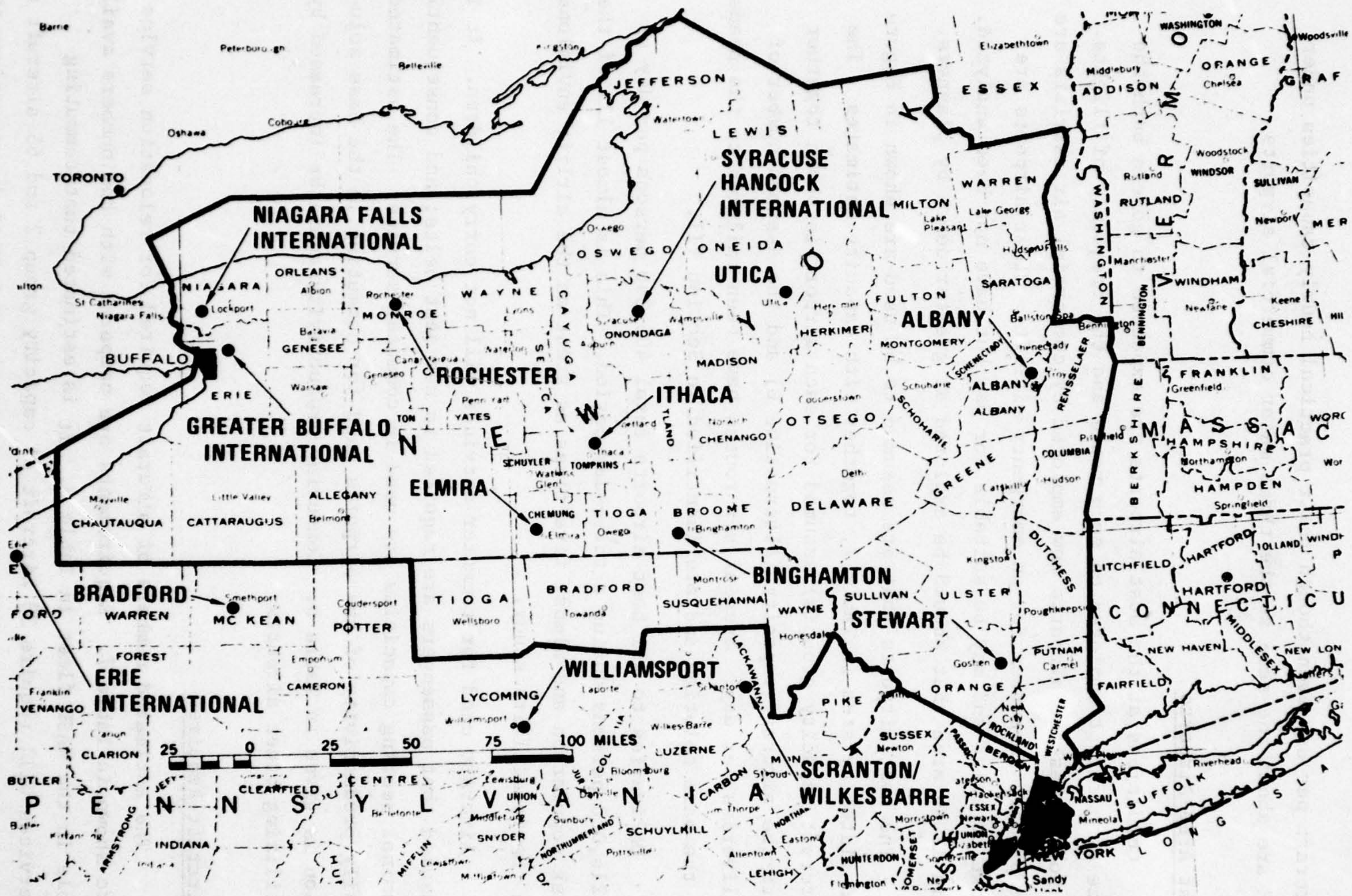

FIGURE 2 HOST AREA AIRPORTS

Table 7

CAPACITY OF HOST AREA AIRPORTS

Airport and County Location	Aircraft Capacity Group	Capacity Alternative B	Delivery Flights Per Day	Persons Per Day	Number of Aircraft Employed
Western area (300 mi)					
New York					
Niagara Falls International,	1	440	54	23,760	10
Niagara	2	300	66	19,800	11
			120	43,560	21
Greater Buffalo International, Erie	2	300	240	72,000	40
Rochester, Monroe	2	300	120	36,000	20
	3	170	60	10,200	9
			180	46,200	69
Subtotal			540	161,760	90
Pennsylvania					
Erie International, Erie	4	120	120	14,400	16
Bradford, McKean	4	120	120	14,400	16
Subtotal			240	28,800	32
Total western area			780	190,500	122
Central area and Albany (200 mi)					
New York					
Albany, Albany	3	170	120	20,400	14
Utica, Oneida	4	120	120	14,400	13
Syracuse Hancock International, Onondaga	2	300	180	54,000	26

Table 7 (Concluded)

Airport and County Location	Aircraft Capacity Group	Capacity Alternative B	Delivery Flights Per Day	Persons Per Day	Number of Aircraft Employed
Ithaca, Tompkins	4	120	120	14,000	13
Elmira, Chemung	4	120	120	14,400	13
Binghamton, Broome	4	120	120	14,400	13
Subtotal			780	132,000	92
Pennsylvania					
Williamsport, Lycoming	4	120	120	14,400	13
Scranton/Wilkes Barre, Lackawanna	4	120	120	14,400	13
Subtotal			240	28,800	26
Total central area			1,020	160,800	188
Southeastern area (100 mi)					
New York					
Stewart, Orange	2	300	180	54,000	33
Grand Total			1,980	405,360	273

*Rounding errors.

Table 8

AIRPORT PRODUCTIVITY FOR COMMUTING

Aircraft Capacity Group	Host Airport	Round Trips Per Day	Seating Capacity	Commuter Round Trips
4	Binghamton	120	90	10,800
4	Elmira	120	90	10,800
4	Ithica	120	90	10,800
2	Stewart	180	230	41,400
4	Utica	120	90	10,800
4	Scranton	120	90	10,800
Total				95,400

Table 9

AIRCRAFT REQUIRED AND AVAILABLE

Aircraft Capacity Group	Number of Aircraft Required	Aircraft in WASP Fleet
1	10	20
2	130	178
3	23	665
4	110	683
Total	273	1,546

Airport Utilization

Details regarding the utilization of airports in the base solution are presented in Section VII. Full utilization of the 14 host area airports was possible and would allow movement of 1,980 loaded flights per day. Only 77% of the assumed emergency capacity of the eight risk airports could be utilized. A larger airlift could be mounted if additional host area airports were available.

Local Travel to Risk Area Airports

Flow rates to the risk area airports will total about 18,000 persons per hour. Trains and large vehicles--buses and trucks--will be the standard modes of travel to risk area airports. Use of automobiles would quickly clog access routes and must be avoided.

The most severe load is expected at JFK, which will handle more flights and larger aircraft than the other airports. Flow rates to JFK may be as high as 8,000 persons per hour. The two NYCTA subway lines near the airport can easily accommodate this flow, but several stations on each line must be used to avoid congestion. Two trains (A and E) serve at least six stations within five miles of the JFK terminal buildings. The most suitable of these stations would be selected.

Much of the travel between stations and JFK will be on expressways. It should be possible for large vehicles to make round trips in one hour or less. The number of vehicles required depends on the average capacity of the vehicle employed. In this study it is assumed that intermediate-sized trucks are used. (Buses would be reserved for main relocation journeys involving longer trips.) The average intermediate truck load is taken as 20 passengers plus luggage. About 400 trucks would be needed on duty at all times to serve JFK plus a reserve of perhaps 80 trucks or almost 500 trucks. Both LaGuardia and Newark airports will be served by subway and trucks. Other airports would be served directly by trucks.

The total number of trucks required for access service at all airports has not been estimated but would be several thousand units. In New York City there are some 22,600 intermediate-sized trucks, about 11,000 of which are believed to be suitable for this service. Consequently, there should be an ample supply of intermediate-sized trucks for ground transportation to airports.

Local Travel from Host Area Airports

Distribution of travelers from host airports appears to be feasible with available resources. An analysis was made of the most severe problems, which are expected to occur at Buffalo and Niagara.

The Buffalo and Niagara airports are within 20 miles of one another and are both in or near risk areas. Relocation operations for local residents and distribution movements for air travelers will have to be coordinated. The population at risk in Niagara is 160,900 persons and all are to be hosted in Niagara County within a few miles of the risk area. In the base solution it is estimated that 252,600 persons from the New York metropolitan area will be airlifted to Niagara and hosted east of the airport in Orleans and Genesee Counties. Distribution of air travelers will require delivery of about 5,060 busloads in three days or about 84 buses per hour (based on effective operations during 20 hours per day). This traffic will require less than half of the capacity of a single, two-lane, two-way highway route. Two highways, NY 429 and NY 31, connect the airport and the host area. Use of those roads for air travelers is unlikely to interfere with relocation of the Niagara population. Therefore, highway capacity is adequate for Niagara.

The population at risk in Buffalo is 985,300 persons. In the base solution the hosting allocations for this population are as follows:

- 623,000 persons remain in Erie County
- 286,300 persons go north to Niagara County
- 213,000 persons go south to Cattaraugus County.

In the base solution it is estimated that 216,000 persons from the New York metropolitan area will be airlifted to Buffalo and hosted east of the airport in Genesee County. Distribution of these air travelers will require deliveries of some 4,320 busloads in three days or 72 busloads per hour, (20 hours per day.) This is about one-tenth the capacity of a single freeway lane. I 90 connects the airport and the host area to the east and would not be required to carry heavy relocation and distribution movements. Therefore, capacity is abundant.

The average ground travel distance from the two airports to host areas in Orleans and Genesee Counties is about 40 miles. Buses would carry about 50 persons plus luggage, and there would be a need to load about 156 buses per hour. Each bus would make a round trip in about

three hours including loading and unloading. Thus there would be a need for about 470 buses on duty plus perhaps 160 on reserve, or a total of about 630 buses. There are more than 3,000 buses registered in the four-county area. Therefore, the supply of buses is abundant.

IV RAIL TRANSPORTATION

Suburban and intercity rail resources have been analyzed, and nine special rail routes have been identified and described. Some resources--such as terminals, rights of way, stations and tracks--are shared by two or more routes (see Figures 3 and 4).

Rail systems have the capacity to transport 2,490,000 persons from New York City. Deliveries can be made as follows:

	Persons (000)
To distant host counties	660,000
To near host areas	720,000
To northern part of risk area	1,170,000
Total	2,490,000

Rail service to the northern part of the risk area is only useful if supplemented by a short bus ride to host territory. Only 151,000 persons are relocated in this fashion.

Rail transportation used in the base solution is presented in Table 20.

Special rail route characteristics and production are summarized in Table 15, Section VII.

Resources and Priorities

The crisis relocation mission will have priority in the use of rail lines, stations, equipment, and personnel. Included are the MTA-Conrail suburban rail systems north of New York, the MTA-Long Island Rail Road system, the suburban rail systems west of the Hudson in New Jersey and New York, other Conrail lines, and all Amtrak lines serving the New York metropolitan area. Equipment and personnel are not fully interchangeable among lines, and some available resources may not be technically suitable for use in places where needed. Shifts of personnel and equipment are discussed below.

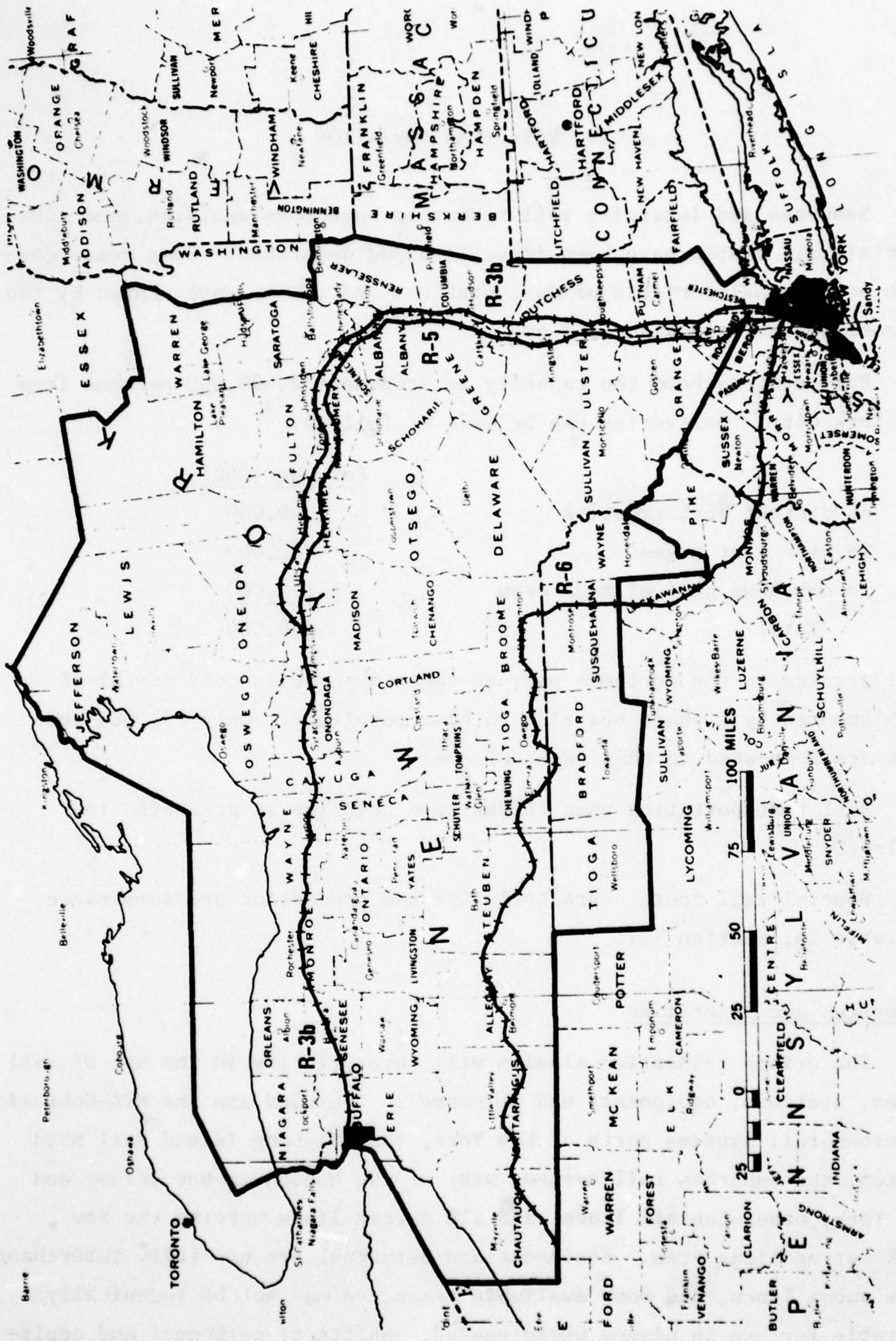

FIGURE 3 RAIL ROUTES TO WESTERN NEW YORK STATE

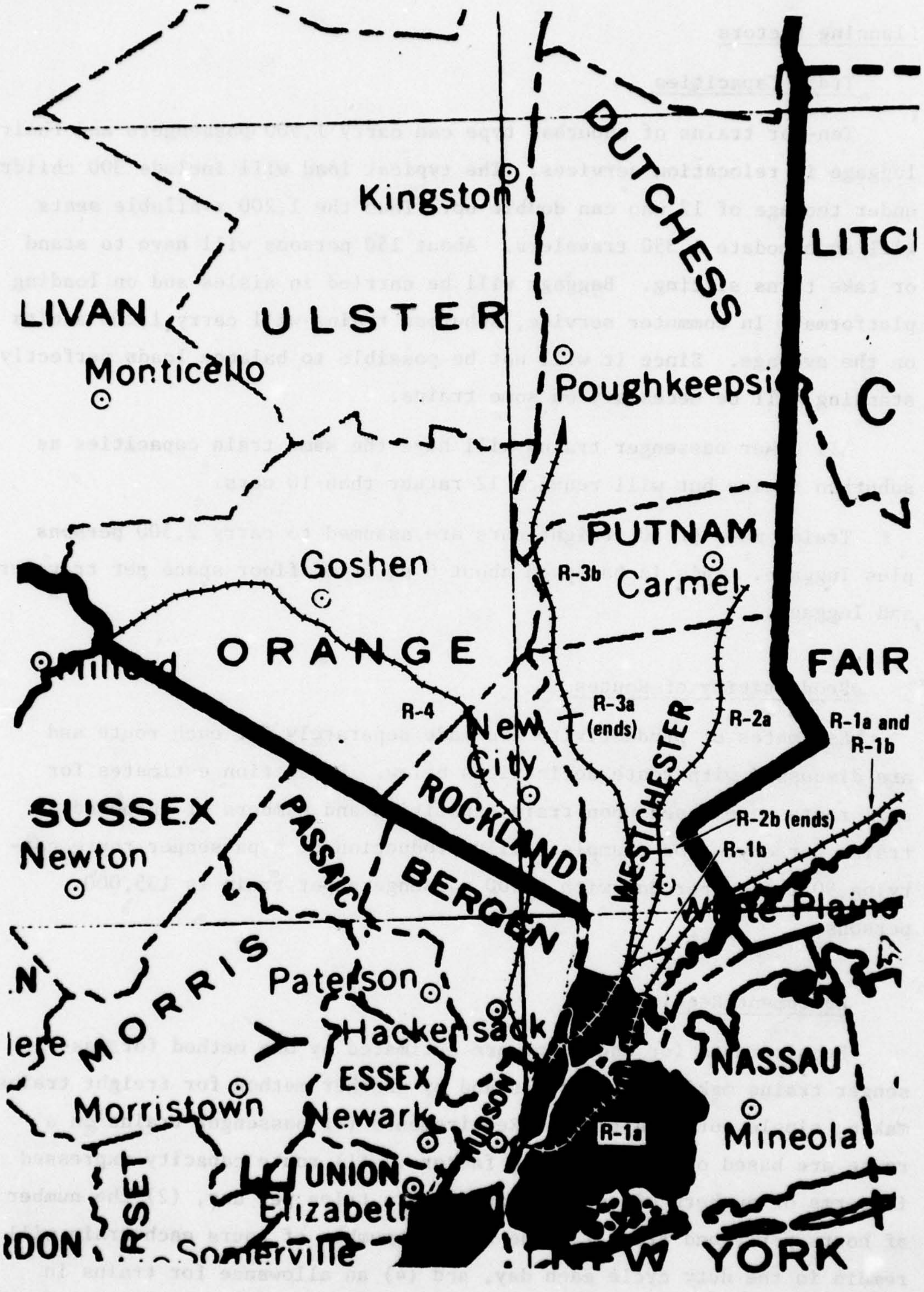

FIGURE 4 SHORT RAIL ROUTES

Planning Factors

Train Capacities

Ten-car trains of suburban type can carry 1,500 passengers and their luggage in relocation services. The typical load will include 300 children under the age of 12 who can double up. Thus the 1,200 available seats will accommodate 1,350 travelers. About 150 persons will have to stand or take turns sitting. Baggage will be carried in aisles and on loading platforms. In commuter service, suburban trains will carry 1,200 adults on the average. Since it will not be possible to balance loads perfectly, standing will be necessary on some trains.

All other passenger trains will have the same train capacities as suburban trains but will require 12 rather than 10 cars.

Trains made of 30 freight cars are assumed to carry 2,500 persons plus luggage. This is based on about 6 sq ft of floor space per traveler and luggage.

Productivity of Routes

Estimates of productivity are made separately for each route and are discussed with route definitions below. Production estimates for rail routes are based upon train capacities and numbers of outbound trains per day. For example, daily production of a passenger route carrying 90 trains per day with 1,500 passengers per train is 135,000 persons.

Equipment Requirements

Requirements for equipment are estimated by one method for passenger trains making round trips and by another method for freight trains making single outbound trips. Requirements for passenger trains on a route are based on the following factors: (1) route capacity expressed in terms of numbers of outbound and return trips per day, (2) the number of hours per round trip, (3) the average number of hours each train will remain in the duty cycle each day, and (4) an allowance for trains in reserve. Estimation of requirements is illustrated as follows:

- A route carries 90 passenger trains per day in each direction.
- Round trip time is 2.5 hours including 30 minutes to load, 45 minutes to travel 30 miles at 40 mph, 30 minutes to unload and turn back, and 45 minutes of inbound travel.
- Trains remain in the duty cycle 15 hours per day. Each train makes six deliveries per day. Fifteen trains and 150 cars are required in services.
- Five trains and 50 cars are required in reserve--being serviced, etc.
- Total requirements are 20 trains and 200 cars.

Requirements for freight cars and locomotives are based on the assumption that each train makes only one outbound trip and then is reassigned to other services as required. It is assumed that each freight train in passenger service includes 3 locomotives and 30 box cars. Thus a route carrying 40 trains per day for three days (120 trains) will require 360 locomotive and 3,600 box cars.

Analysis of Special Rail Routes

Route R-1a

Route R-1a on the New Haven Line will operate over electrified suburban rail lines between Grand Central Terminal (GCT) and a group of three stations in Westchester County near the Connecticut state line (see Figure 4). The stations are Pike, Rye, and Port Chester. (Several Connecticut stations could be used if needed.) The route is about 30 miles long. All of the delivery stations are in risk territory. Final delivery to host areas will be via bus.

Route R-1a now carries 90 trains per day to and from GCT. There is considerable variation in frequency throughout the day and night. Under the "steady-state" operating conditions envisioned for relocation and commuting operations it is assumed that the route can carry 1 train every 10 minutes in each direction. With allowances for delays and missed trips the daily productivity of the route is equivalent to 20 hours of steady-state operations.

This assumed that Route R-1a will carry 120 trains per day in each direction. With 1,500 passenger loads, the productivity of Route R-1a

is estimated at 180,000 persons per day or a total of 540,000 persons in a three-day period. Capacity in commuter service, with 1,200 persons per train each way, is 144,000 persons making round trips each day.

The capacity of Route R-1a is not expected to be constrained by lack of equipment. The route is now served by 340 multiple-unit (MU) electric cars. The duty cycle for trains is assumed to be 2.5 hours including 30 minutes at GCT, 45 minutes of travel at 40 mph, 30 minutes to unload and turn back at the delivery station, and 45 minutes of return travel. A train kept in the duty cycle 15 hours each day would make six deliveries. Thus, to fully utilize the route, 15 trains would be required on duty and 5 additional trains in reserve. However, route R-1a is not fully utilized because it delivers to stations in risk territory. The base solution found no use for the productivity of the route. Thus, the 340 cars, which are technically suitable for use on Routes R-2b and R-3a, are available for reassignment.

Route R-1b

Route R-1b will operate over Amtrak's electrified line from Penn Station to Long Island and the Bronx where it will then join Route R-1a on the New Haven Line and continue to the same delivery stations near the Connecticut border. The route is about 30 miles long. The route now carries 21 trains in each direction each day, and it is assumed that this can be increased to 60 trains. Thus the maximum productivity of the route in relocation service is 90,000 persons per day and 270,000 persons in three days. Capacity for commuters is 72,000 persons making round trips each day. In the base case it was found that Route R-1b need not be used.

Route R-1b uses electric locomotives and trailed cars. If used for relocation service, the route would require about 10 locomotives and 120 cars to achieve the indicated production. However, since the route is not needed, it has been assumed that the Amtrak equipment normally used on Route R-1b can be used on other routes.

Route R-2a

Route R-2a on the Harlem Line shares an electrified line with Route R-2b from GCT to North White Plains in Westchester County and then continues over nonelectrified track to a group of six stations in host territory. The first and last stations in the host area are Bedford Hills in Westchester County and Brewster in Putnam County. The route is about 45 miles long.

Route R-2a will be served by dual-powered FL-9 locomotives and coaches that are now employed on the line. FL-9 locomotives have a diesel-electric propulsion system for normal operations and a third-rail electric propulsion system for underground operations in and near GCT.

Trains on Route R-2a will have a cycle time of about 4.25 hours. In a 15-hour day each train will average 3.53 round trips. Route R-2a now carries 26 trains per day in each direction. In the relocation operation it is assumed that the route will carry 40 trains per day in each direction. Route productivity in relocation service would be 60,000 persons per day or 180,000 persons in three days. Commutation capacity would be 48,000 persons making round trips each day.

Route R-2a will require about 15 trains--11 in the duty cycle and 4 in reserve--or 15 locomotives and 150 cars. MTA has 43 FL-9 locomotives but only 100 locomotive-drawn coaches. It is assumed that needed coaches--about 50--will be obtained from nonessential routes such as the nonelectrified routes of the Long Island Rail Road.

Route R-2b

Route R-2b on the Harlem Line operates over electrified tracks on a line shared with Route R-2a between GCT and North White Plains plus other nearby stations. The route is about 24 miles long. The destination stations of Route R-2b are in the risk area. Distribution to host areas via bus will be necessary.

Route R-2b now carries 85 trains in each direction each weekday. It is assumed that this line will carry up to 120 trains per day to

North White Plains--Route R-2a will operate 40 trains and Route R-2b can operate 80 trains. Productivity of Route R-2b is 120,000 persons per day or 360,000 persons per three days. Commutation capacity is 96,000 round trips per day.

Cycle time on this route is about 2.2 hours. Trains kept in the duty cycle 15 hours each day will average 6.8 deliveries per day. At full capacity, about 16 trains and 160 cars are required: 12 trains (120 cars) in the duty cycle and 4 trains (40 cars) in reserve. Routes R-2b and R-3a share a fleet of 278 MU electric cars. If R-2b were fully loaded, 160 cars would be used. However, in the base solution only 151,000 persons are relocated via R-2b, and only 42% of the capacity is used. Therefore, only about 70 cars are needed. This leaves 208 cars for R-3a.

Proposals have been made to extend electrification of the Harlem Line from North White Plains to Brewster in Putnam County. This change is highly desirable from the viewpoint of crisis relocation. MU electric cars would be substituted for existing FL-9 locomotives and trailed cars. Routes R-2a and R-2b would be combined into a single route--R-2--which would terminate at Brewster in the host area. Route R-2 would then relocate 540,000 persons to the host area in three days and would provide round trip commute service for 144,000 essential workers.

Route R-3a

Route R-3a, on the Hudson Line, operates over one of two pairs of electrified tracks on lines between GCT and Croton-Harmon (and other stations in the vicinity) (see Figure 4). The route is about 33 miles long. Delivery stations are a short distance within the host area.

Cycle time will be 2.67 hours. Trains will average 5.62 deliveries per 15-hour day. This line now carries 54 suburban trains per day. It is assumed that the number can be increased to 80. Productivity of the line will be 120,000 persons per day or 360,000 persons in three days. Commutation capacity will be 96,000 round trips per day.

About 19 trains including 190 cars are required for this route with 14 or 15 trains in the duty cycle and the remainder in reserve. As previously noted, the Hudson and Harlem Lines share an equipment pool. After assignment of cars to the Harlem Line, 208 cars remain in the Hudson-Harlem equipment pool. Thus availability of equipment is not a constraint.

As indicated above, the New Haven Line (Route R-1a) has a surplus of 340 cars which can be used on the Hudson and Harlem Lines. It is assumed that part of these cars (plus crews) will be used if needed to increase reserves.

It is noteworthy that the Long Island Rail Road employs some 800 MU electric cars that are nearly identical to the cars used on Routes R-2a and R-3a and similar to the cars used on Route R-1a. These cars are not usable on the Hudson, Harlem, and New Haven Lines at present because of minor technical differences, but from the viewpoint of crisis relocation operations, it may be desirable to make changes needed to achieve interchangeability of MU equipment among all lines.

Route R-3b

Route R-3b is the Amtrak route to Buffalo. It operates over the second pair of electrified tracks on the Hudson Line from GCT to Croton-Harmon and continues on double-track nonelectrified line (see Figure 3). Amtrak equipment can be used. FL-9 locomotives are now used on the line from GCT to Croton-Harmon. Line-haul diesel-electric locomotives are used thereafter. Coaches normally used on this line will be employed plus augmentations from other Amtrak routes.

Route distances from Grand Central Terminal, New York, to reference points in host counties are summarized below:

Croton-Harmon, Westchester	33
Cold Springs, Putnam	51
Poughkeepsie, Dutchess	72
Hudson, Columbia	113
Albany, Albany	144

Amsterdam, Montgomery	178
(Centroid),* Herkimer	190
Utica, Oneida	238
(Centroid),* Oneida	246
Rome, Oneida	252
(Centroid),* Madison	276
Syracuse, Onandaga	286
(Centroid),* Cayuga	306
(Centroid),* Wayne	330
Rochester, Monroe	372
(Centroid),* Genesee	404
Buffalo, Erie	438

In the base solution, Route R-3b delivers people to Cayuga (87,000) and Tompkins (93,000) Counties. The Amtrak route now carries 8 trains per day out of GCT. It is assumed that this can be increased to 40 trains per day under emergency conditions. Thus 120 trains would be loaded and dispatched in three days. It is expected that Route R-3b trains will deliver to host counties west of Albany. Average trips are about 300 miles, and cycle time will be about 14 hours. This includes 1 hour for loading and terminal delays, 12 hours travel at 50 mph, and 1 hour for unloading and turnback.

In the base solution, deliveries over Route R-3b average 60,000 persons per day or 180,000 persons in three days. The route near the risk area is used for commuting service after relocation is complete and provides 48,000 round trips per day.

About 43 trains will be needed for Route R-3b including 32 in service and 11 in reserve. The trains will include 86 locomotives and 516 cars. Amtrak has about 300 locomotives and 2,000 cars in its national equipment inventory. More than 40% of Amtrak's traffic is on routes entering New York City. It is assumed that up to 120 locomotives and up to 800 cars could be marshalled in the New York metropolitan

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* A centroid is the approximate midpoint of a route through a host county.

area quickly enough for relocation service. As indicated above, the Amtrak route from New York to Boston via the New Haven Line--Route R-1b--is not required for relocation service. It also appears that trains between New York and the South could be diverted. It is assumed that Route R-3b has first claim on Amtrak's equipment and crews in the New York metropolitan area. It is also assumed that the requirements of Route R-3b can be met and that an inventory of about 114 locomotives and 284 cars would remain for possible use on other routes.

Route R-4

Route R-4, the Port Jervis Line, operates on double-track Conrail line (formerly Erie-Lackawanna) between Hoboken, New Jersey, and Port Jervis, New York--a distance of 87 miles. Route R-4 can be used for relocations to numerous communities in Orange County. Average travel distance is 50 miles. It is assumed that the route will deliver 40 train loads per day. Productivity is 60,000 persons per day or 180,000 in three days. Commutation capacity is 48,000 round trips per day.

Cycle time is estimated at 3.5 hours. Each train will make an average of 4.3 deliveries in a 15-hour day. About 13 trains are required--9 or 10 in service and the remainder in maintenance or reserve. Thus the route requires about 13 locomotives and 130 suburban cars.

Passenger service on Route R-4 is small in amount. Consequently augmentation of equipment and crews will be necessary. Other suburban railroads operating in New Jersey have 13 electric locomotives, 70 diesel-electric locomotives, and 387 trailed cars. These lines appear to have no relocation missions. The needs of Route R-4 will be met from this source and a remainder of about 57 locomotives and 257 cars will be available for use on other routes.

Route R-5

Route R-5, on the Westshore Line, will operate on a single-track freight line along the Hudson River. The route will start in piggyback

freight yards in Hoboken, New Jersey, opposite Manhattan. It will use the Westshore Line to Albany. From Albany west it will use a route parallel to R-3b, to Utica. Thereafter, it will share track with R-3b, if service is needed.

In the base solution, trains made up of locomotives and freight cars are used on Route R-5. Equipment will be marshalled in New Jersey, loaded, and dispatched to host counties. After making one passenger delivery, the equipment will be reassigned to freight service.

Freight equipment is used on Route R-5 because passenger equipment is likely to be in short supply and the line is single tracked and offers limited capacity for two-way flow. However, if passenger equipment from the Long Island Rail Road and the New Haven Line could be exploited, or if equipment can be found from any other source, it would be possible to operate Route R-5 for two-way traffic.

Reference points and distances to host counties west of Albany are assumed to be the same as for Route R-3b. In the base solution, Route R-3b delivers people to Cayuga County. The average travel distance is 300 miles. Travel time will average 7.5 hours at 40 miles per hour. An hour is allowed for loading.

It is assumed that 40 trains per day can be dispatched over Route R-5. Each train will carry 2,500 passengers. Productivity of the route is 100,000 persons per day or 300,000 persons in three days. The line is not used for commuting.

Equipment requirements for the three-day period are estimated at 360 locomotives and 3,600 boxcars, based on 3 locomotives and 30 cars per train, 40 trains per day, and three days of operation. There are more than 28,000 locomotives and more than 300,000 "plain" box cars (i.e., without special racks or fixtures) in the United States, and a substantial fraction are in the New York area. The requirements for Route R-5 appear very small in comparison with available resources.

Route R-6

Route R-6, the Binghamton and western counties line, uses double-track lines from Hoboken, New Jersey, west through Scranton, Pennsylvania, north through Binghamton, New York, and west across the entire state of New York in the southern tier of counties. Parts of the line near Hoboken are electrified but diesel locomotives can be used over the entire route. It is expected that locomotive-drawn passenger coaches will be used, if available, and would make round trips. Line capacity not used by passenger trains will be used by passenger-carrying freight trains making one-way trips outbound, as on Route R-5.

Several potentially useable risk area terminals are available near Path subway stations and highways providing easy access via bus from Manhattan.

Route distances from Hoboken to reference points in host areas served by Route R-6 are summarized below:

(Centroid), Susquehanna, PA	165
Binghamton, Broome, NY	195
Owego, Tioga, NY	220
(Centroid) Bradford, PA	235
Elmira, Chemong, NY	252
Corning, Steuben, NY	271
(Centroid), Steuben, NY	290
Hornell, Steuben, NY	312
Wellsville, Alegany, NY	338
Olean, Cattaraugus, NY	375
Salamanca, Cattaraugus, NY	393
Jamestown, Chautauqua	427

In the base solution, Route R-6 delivers people to Steuben County. For productivity calculation it is assumed that the average travel distance via rail is 320 miles (e.g., Steuben County, NY). Trains will travel at 40 miles per hour. One hour is allowed for terminal activities at each end of the trip, and running time is

8 hours each way. Cycle time for passenger trains is 18 hours. It is assumed that each train will make 0.83 round trip per day. The route is assumed to carry 40 trains per day. Route productivity will be 60,000 persons per day or 180,000 persons in three days. If suburban cars are used, there is a need for about 64 locomotives and about 640 cars on duty and in reserve.

Route R-6 will be served by passenger trains, if equipment can be found, or by a mixture of passenger and freight equipment. One hundred and seventy-one locomotives and 541 passenger cars are available (and not otherwise assigned) from the Amtrak and New Jersey commuter railroad equipment pools. Thus there is a shortage of about 100 passenger cars or about 10 trains.

A special study will be needed to see if surplus cars from Route R-1a and from the Long Island Rail Road can be used. If not, freight trains and cars would have to be used. This appears feasible; consequently, lack of equipment should not constrain production.

Local Travel

Subways will be the primary mode of access to railroad stations and yards. Subways serve the three passenger stations to be used-- GCT and Penn Station in Manhattan and Hoboken in New Jersey. Highway vehicles will only be needed to collect passengers for trains made of freight cars. It is assumed that these trains will be loaded at piggyback yards in or near Hoboken. This would involve about 335,000 persons or about 4,700 persons per hour from the Path subway station at Hoboken to the freight yards.

Highway transportation will be used to distribute travelers from rail delivery stations to host sites. These services will be provided by buses, trucks, and autos in the host counties. Average delivery distance will be kept as short as possible. It appears that transportation resources for distribution of rail travelers are in abundant supply, and detailed analyses have not been made.

V WATER TRANSPORTATION

The Hudson River is a major waterway for movements of petroleum and freight in normal times. In a crisis the river can be used for relocation operations as well as for the transportation of supplies. The capacity of the waterway for passenger transportation will be determined by the availability of vessels and crews, and by port capacities in the host counties.

Estimates of productivity of water transportation of each type have been stated in terms of ranges. The values are recapitulated in Table 10.

Table 10

PRODUCTIVITY OF VESSELS

	Production Ranges	
	Lower	Upper
Ocean vessels		
Break-bulk freighters	120,000	180,000
Passenger liners	8,000	20,000
Ferries and small passenger vessels		
Staten Island	75,000	120,000
Cruise boats	14,000	52,000
Tugs and barges	25,000	75,000
Fishing vessels and pleasure craft	not est.	not est.
Total	242,000	447,000

In the base solution 300,000 persons are relocated in three days via water.

Host Area Ports

Vessels can unload directly to docks or can anchor and unload to barges and tugs at numerous points along the Hudson. A detailed study of host ports was not made. Generally, it will be desirable to move people as far north as possible because this gives maximum relief to overloaded highways. The allocation of the population transported by water in the base solution is shown in Table 16, Section VII.

Risk Area Ports

Port capacity, support services, fuel, and other resources are abundant in the risk area and will not limit use of water transportation. Loading facilities include the new passenger ship terminal on the West Side of Manhattan, ferry slips at Battery Park on Manhattan and on Staten Island, and numerous piers and docks along the Hudson and East Rivers. Travel from residences to loading points will be via subway and suburban trains supplemented by intermediate trucks (as for air and rail).

Channel

The controlling depth of the Hudson River Waterway System is 32 feet from New York City to Albany and 14 feet for at least ten miles further north. Channel widths are 350 feet or greater to Albany. The turning basin at Albany can accommodate vessels of slightly under 600 feet in length. Currents are generally less than two knots and vary in direction with tidal flows. Tidal variations are in the range of 4 to 5 feet.

Vessels and Capacities

The principal groups of water craft are ocean vessels, ferries and other small passenger vessels, tugs and barges, and fishing boats and pleasure craft.

Ocean Vessels

Break-Bulk Cargo

Break-bulk cargo vessels have a considerable potential capacity for passenger service in an emergency. Such vessels can operate to Albany. United Fruit, for example, presently has ocean-going ships sailing in and out of the Port of Albany on a regular basis.

Break-bulk vessels vary in size and draft. Vessels of typical design have three sheltered decks and a main deck exposed to the weather. If possible, passenger loads should be limited to the sheltered decks. Most vessels have ventilation.

Vessels of the C-4 class, chosen here as typical, have a draft slightly less than 32 feet under full load and still less when lightly loaded as will be the case with passengers. Typical C-4's have more than 50,000 sq ft of sheltered deck. If there were no cargo on board, a C-4 could carry up to 8,000 persons in sheltered space with an average space allowance of 6 sq ft per person.

Ships in port at the start of an emergency will generally be partly loaded, and it is doubtful that all cargos can be discharged completely. It is assumed that 30 of the 70 to 80 vessels ordinarily in the harbor on any given day will become available for emergency passenger service during the relocation period. Ships can be moved to suitable loading points of which there is a wide choice.

The average vessel is assumed to be half loaded with cargo and will carry 4,000 persons. Each vessel will make a single trip. Under these assumptions 30 break-bulk vessels would relocate 120,000 persons. Under very urgent conditions, passengers could be carried on main decks as well as in sheltered spaces, and capacities thus could be increased to 6,000 persons per vessel or to a total of 180,000 persons during the operation.

Container Ships, Bulk Carriers, and Tankers

Container ships, bulk carriers, and tankers have relatively small amounts of sheltered deck space where passengers could be carried. The vessels would have low productivity and would tend to congest port facilities in the host area. Many are too long to be turned at Albany and would have to be unloaded by tugs and barges at intermediate points. Consequently, the assumption made here is that the use of these vessels should be avoided if possible. However, if conditions are sufficiently urgent, it would probably be possible to utilize 50 such vessels to carry 500 persons on each vessel and to relocate a total of 25,000 persons.

Passenger Liners

Passenger liners will make only a small contribution to relocation operations. About 12 vessels visit the Port Authority passenger terminal on Manhattan regularly, and each reenters the port about every 11 days. On the average, about one liner per day enters the port. It is common practice for vessels to come in on Thursday and to leave Saturday morning. There is no assurance that any given number of liners will be in port at the outset of an emergency. However, on the average, two liners would be in port and three more would arrive during the relocation exercise if not diverted while at sea.

Capacities of passenger liners vary from 550 to 2,700 in normal service, and it is assumed that the average is 1,000. At the outset of an emergency some will have normal passenger loads on board. It is assumed that the average vessel will be able to accommodate 3,000 new passengers boarding in New York and will make one delivery. Total relocation capacity for New York residents would be in the range of 8,000 to 20,000 persons.

It is assumed that ocean vessels can be loaded in five hours and can travel to the vicinity of Albany (about 150 miles) in ten hours and to intermediate ports in shorter times, according to the distance. It is also assumed that a vessel can be unloaded while at anchor in five hours by two tugs, each with one barge. Unloading operations must be

carefully scheduled and supervised to avoid port and channel congestion. Therefore, a number of unloading points will be required. After unloading, ships should move out of the way of other traffic and anchor at suitable places in host territory.

Ferries and Small Passenger Vessels

Staten Island Ferries

The Staten Island ferries are important resources. There are six vessels in existence, but one is usually in drydock. Ordinarily five vessels are used for round trips between the Battery on Lower Manhattan and St. George on Staten Island. During a relocation operation the vessels would load at Manhattan or Staten Island, as required, deliver to counties along the Hudson, and return for additional loads. Ferries have 14-foot drafts and could travel about 10 miles north of Albany to the vicinity of Troy.

Three ferries have normal capacities of 3,500 passengers, and three have normal capacities of 3,100 passengers. All use most of the lower deck for the carriage of automobiles. Emergency load limits of these vessels were not determined. In the base solution passenger loads are increased to an average of 5,000 persons plus luggage by exploiting the auto deck and by crowding.

Existing facilities for loading ferries are very highly developed, and it is assumed that loading and other terminal delays will require one hour. Travel time to Albany or Troy will be about 11 hours. Because ferries are to make round trips it is desirable to keep unloading time to a minimum. The shallow draft of ferries will allow exploitation of docks not useable by larger vessels. Otherwise, barges and tugs would be used where suitable docks cannot be found. Unloading is likely to require more time than loading; three hours has been allowed. Return would require 11 hours. An allowance of four hours is made for refueling, repairs, and other delays during each round trip. Thus a round trip to Troy would require 30 hours. At the end of a 72-hour period a vessel would have made two round trips and be well out of the risk area with its

third load. Thus, a fleet of five vessels could relocate 75,000 persons. Production could be increased by shortening trips or increasing loads. For example, if each ferry made four deliveries of 6,000 persons, the total number would be 120,000.

Cruise Boats

Cruise boats operate from piers on the West Side of Manhattan and provide service in the New York Harbor and up the Hudson to West Point. One vessel with a normal capacity of 3,500 persons serves West Point and is assumed to carry 5,000 persons with crowding. There are ten smaller vessels with an average capacity of about 600 passengers. With crowding, these vessels are assumed to carry 800 persons each. Thus, the entire fleet has the capacity to transport about 13,000 persons in one lift.

The operation of cruise boats is seasonal. At the most favorable time of year and with all 11 boats in service, it is assumed that the fleet could deliver 52,000 persons, in four deliveries, to West Point and vicinity. Smaller numbers of vessels are used in spring and fall and *there is very little service* in the four-month period from December through March. Boats not in service are laid up in Brooklyn and could not be manned and made ready for service in three days. It is assumed that the lower limit of capacity would allow relocation of 14,000 persons in three days.

Tugs and Barges

In the New York Harbor there are about 125 tugs, 200 open barges, and 50 covered barges. It is assumed that all of the tugs are useable for crisis relocation service and that half of the barges--100 open and 25 covered--are empty and useable.

Tugs and barges can provide a number of useful services. It is assumed that 25 tugs will be used to assist large vessels at risk area and host area ports. Another 25 tugs and 25 open barges will be used in host areas to transport passengers from anchored vessels to docks.

It is assumed that a tug and barge can move 400 persons per trip. This allows 6 sq ft per person. The fleet would average 2.5 round trips in three days. Average productivity is 1,000 passengers per tug and barge.

If only covered barges are used, 25 tugs and 25 barges would move 25,000 persons. If open barges are also used, then 75 tugs, 25 covered barges, and 50 open barges would transport 75,000 persons.

Fishing Boats and Pleasure Craft

Fishing boats and pleasure craft have a significant potential for relocation service. Pleasure craft have the added advantage of providing attractive shelter for the occupants. Limitations of time and access to data precluded estimates for these two classes of water craft.

VI HIGHWAYS

Highway transportation must be exploited fully and effectively to accomplish timely relocations of the New York metropolitan area risk population. In the feasibility study, hourly highway capacities were estimated at a cordon along the north borders of Westchester and Rockland Counties. Estimates of the three-day productivity of available highway routes were based on the cordon estimates. In the present study the method of analysis has been broadened to treat special highway routes that extend from points within the risk area to all of the counties used for hosting.

In the base solution 7,944,300 persons were relocated via highway in automobiles and buses. Large-capacity trucks can be used to supplement buses, but this may not be necessary. The bus operation would employ about 4,880 vehicles, accommodate 1,758,500 persons, and require 3.0 days. The automobile operation would employ 1,999,400 first autos, accommodate 6,185,800 persons, and require 3.3 days. Alternative solutions analyzed means to shorten the duration of relocation operations.

The characteristics of highways and other highway transportation resources are described in this section. Detailed information on highway routes appears in Appendix A. The best scheme for utilizing highways is not immediately evident and was worked out in a series of trials. The method of analysis is described in Section VII. Bottleneck capacity and production of each special highway route are presented there in Table 17.

Special Highway Routes

Nine special highway routes are identified and described in this section together with supplemental routes and branches. Special highway routes utilize the major highways of the region including I 684, I 84, I 87 and I 90; the major parkways (Taconic, Palisades, Hutchinson

River, and a portion of the Saw Mill River); NY 17; and numerous two-lane highways. Special highway routes combine parts of several highways, which are listed by number or name. Numerous feeder and distributor routes must be used for local transportation in risk and host areas, but these were not studied in detail.

The selection of highway routes was influenced by analyses of the characteristics of individual highway links and their connections, and information regarding relocation needs. A series of trial solutions was conducted. Each iteration included an allocation analysis of the risk population and a transportation analysis. The transportation analysis included route definitions, capacity estimates, and productivity calculations. The allocation analysis used defined routes and the productivity of each route to aid in selecting destinations of numerous population groups and to estimate relocation time. These analyses interact with one another (e.g., results of each allocation provide guidance for the redefinition of routes and for the adoption of measures to increase highway productivity). Numerous iterations were made before the process was concluded with the base solution presented in Section VII.

Information regarding highways was obtained mainly from maps and documents published by New York State. Other sources of information included commercial maps, and interviews and telephone conversations with personnel of the New York State Department of Transportation, the East Hudson Parkway Authority, the Palisades Interstate Parkway Commission, and the County of Westchester. Highway capacity estimates are based mainly on information obtained from the New York State 1972 highway sufficiency ratings. Although some later data were obtained by interviews, most of the information used was at least five years old. It seems likely that some sections of highway will have been upgraded by now and that other improvements will be made in the near future. Therefore, capacities used in this report may be somewhat lower than actual current capacities and near-future capacities.

It is likely that the special highway routes defined here can be improved in the preparation of plans by using more detailed information and by further iterations. However, expenditures of further effort aimed at the improvement of estimates was not possible in this research.

Measures to Enhance and Preserve Highway Capacity

Numerous measures have been taken to enhance or preserve capacity on special highway routes. Some routes are supplemented by parallel highways to avoid limitations of capacity from bottlenecks. Some routes are branched to exploit two or more highways when this practice will preserve and extend route capacity. Some routes are relatively circuitous rather than direct; this is done when the extra route length allows fuller exploitation of available capacity. Care has been used to avoid conflicting intersections where two traffic streams would interrupt one another, and to minimize effects of conflicts when the occur. When special routes closely approach or intersect one another, several highways are sometimes used to balance capacities and loads and to avoid a potential bottleneck.

Work was limited to the identification and analysis of the "trunk" elements of special highway routes and did not include study of feeder roads in the risk area or distributor roads in host areas. Brief study indicated that highway capacities on Long Island and in New York City to the Bronx-Westchester County Line and across the Hudson to New Jersey are much greater than the capacities of the special highway routes. The same condition appears to exist within host counties between the exits from special routes and host sites.

It has been assumed that diligence will be used to prepare for relocation and to develop and exploit the potential capacity of highways but that investments in new construction (e.g., for relief of bottlenecks) would be small. Measures to be taken in advance include route planning; preparation of route markers; arrangements for constant surveillance by air, road, and stationary observers; preparations for strict management and control of operations through a well-developed

communications system and control center; and plans for maximum deployment of emergency road service personnel and vehicles including auxiliary forces capable of removing vehicles and clearing traffic stoppages by expedient measures.

It has also been assumed that some losses of highway capacities will inevitably occur. Losses will result from inability to load routes adequately at all hours of the day and night; congestion caused by overloading; and delays in clearing stoppages caused by accidents, breakdowns, and driver errors. Allowance for such losses has been made by an assumption that the daily productivity of a route is equivalent to 20 hours of operations at the effective capacities.

Numerous conventional and unconventional methods of highway operation have been considered although all were not used. Among these are:

- Normal usage of highways with
  - all automobile traffic
  - various mixes of autos and large vehicles--buses and trucks
  - all large-vehicle traffic.
- Conversion of all lanes to outbound travel
  - all automobile traffic
  - various mixes of autos and large vehicles.
- Normal use of outbound lanes of freeways for automobile traffic and conversion of the inbound lanes to two-direction movement of large-vehicle traffic.
- Other conversions--see the description of Route H-70 below.

An operation method was chosen for each route, based upon needs for service, availability of vehicles, the productivity of the route under various operating alternatives, and the relative location of the route with respect to other routes capable of accommodating the back-haul movements of supply trucks and emergency vehicles. The availability of back-haul routes becomes important when the conversion of a route to all outbound traffic is considered because a way must be found for a small number of vehicles to travel in the inbound direction. Since two-way routes must be preserved to meet this need, it is not feasible to convert all roads to outbound traffic.

The capacity of a route is estimated by the application of traffic engineering principles and procedures. Capacity is defined as the hourly service volume (vehicles per hour) at the bottleneck section of a route. Highway capacities are first computed for autos. The service volume of each route in each county was calculated according to the factors and procedures of the Highway Capacity Manual* and is calculated at level-of-service D, as defined in the manual. In calculating highway capacities, it was assumed that the restricted average highway speed is 50 mph for all undivided highways. It was also assumed that a small number of supply trucks delivering food, fuel, and other essential items travel on these routes that will be used primarily for evacuating people by autos. Though the estimated numbers of supply trucks are much less than 1% of total traffic, calculations of capacity were based on 1% trucks in the traffic stream.

Highway capacities for bus and truck traffic are computed by combining estimates of capacities for autos with reduction factors. The reduction factors are one bus or truck versus two autos in level terrain, one bus or truck versus 4 autos in rolling terrain, and one bus or truck versus six autos in mountainous terrain.

For uncontrolled-access highways, capacities have been computed according to the Highway Capacity Manual and then reduced 20% to allow for minor interruptions of flow, such as turning and crossing movement by police and supply vehicles, and for other frictional factors. This reduced capacity is defined as the effective capacity. No capacity reduction was made for controlled-access highways; therefore, the effective capacity of controlled highways is the same as the capacity computed according to the manual.

Effective highway capacity is an input for estimating daily productivity.

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*Highway Capacity Manual, Transportation Research Board, Washington, D.C. (1965).

Route Descriptions

Each route is described briefly below; and in detail, with bottleneck capacities noted, in Appendix A.

Highway routes are presented in Figures 5 through 8, which show county and state boundaries and principal cities.

The highway capacities and production data generated in the base solution are summarized in Table 17, which appears in Section VII.

Route H-10

Route H-10 follows NY 22, with minor exceptions, along the eastern boundary of New York State through Westchester, Putnam, Dutchess, Columbia, Rensselaer, and Washington Counties and terminates in Essex County. Route segments are:

- US 1 from Bronx County line to Port Chester (Westchester County)
- NY 120 Port Chester to Armonk (Westchester County)
- NY 22 Armonk to Essex County.

The majority of the route is two-lane. It is operated as an all-auto, one-way outbound highway through Dutchess County.

Route H-20

Route H-20 proceeds north from the Bronx County line through Westchester and Putnam Counties and terminates at the northern boundary of Dutchess County near Pine Plains. Route segments are:

- NY 22 from Bronx County line to White Plains (Westchester County)
- NY 141 White Plains to Chappaqua (Westchester County)
- NY 120 Chappaqua to Millwood (Westchester County)
- NY 100 and NY 35 Millwood to Amawalk (Westchester County)
- NY 118 and US 6 Amawalk to Carmel (Putnam County)
- NY 52 Carmel to Stormville (Dutchess County)
- NY 216, NY 55, and NY 82 Stormville to the northern boundary of Dutchess County.

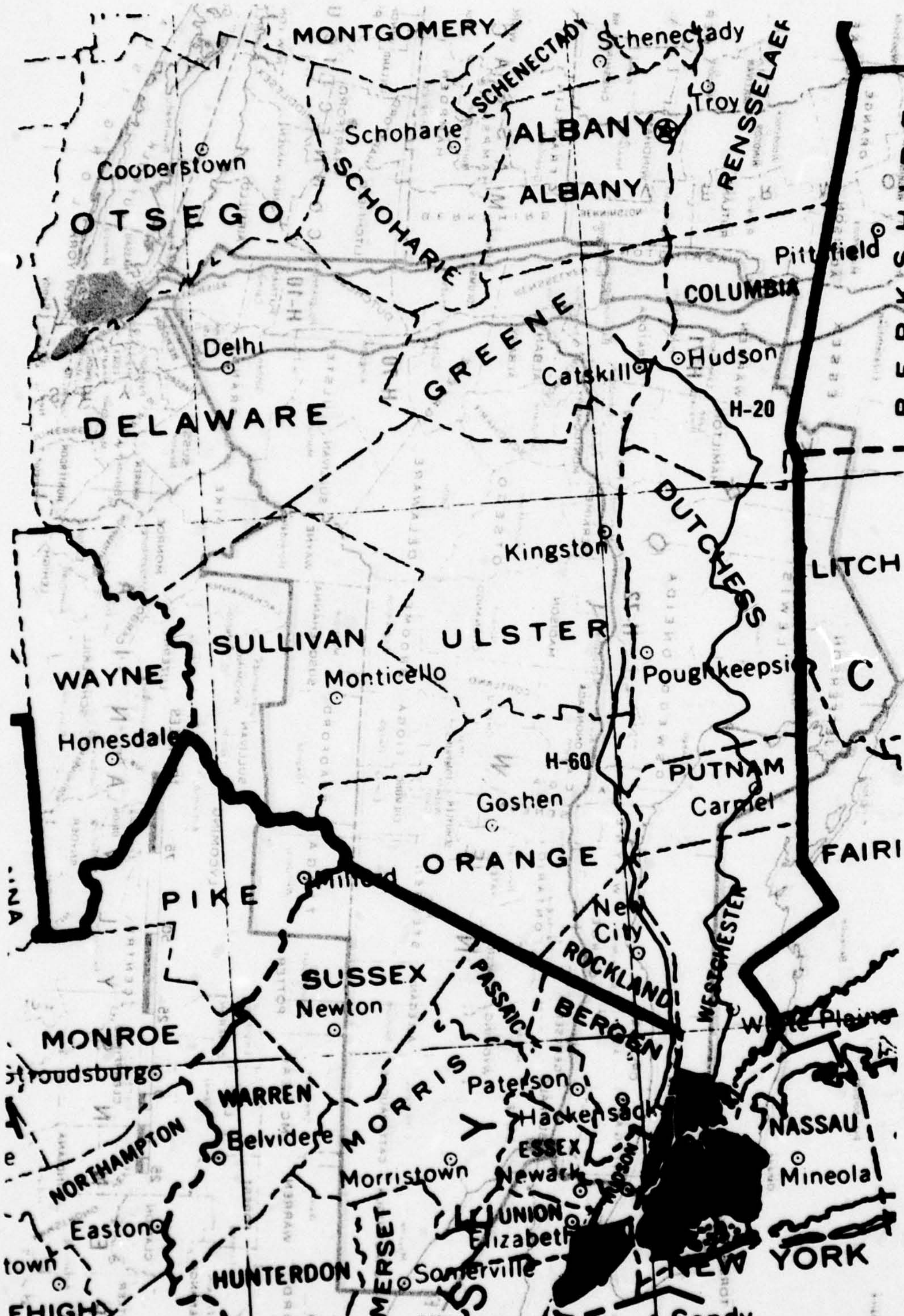

FIGURE 5 HIGHWAY ROUTES H-20 AND H-60

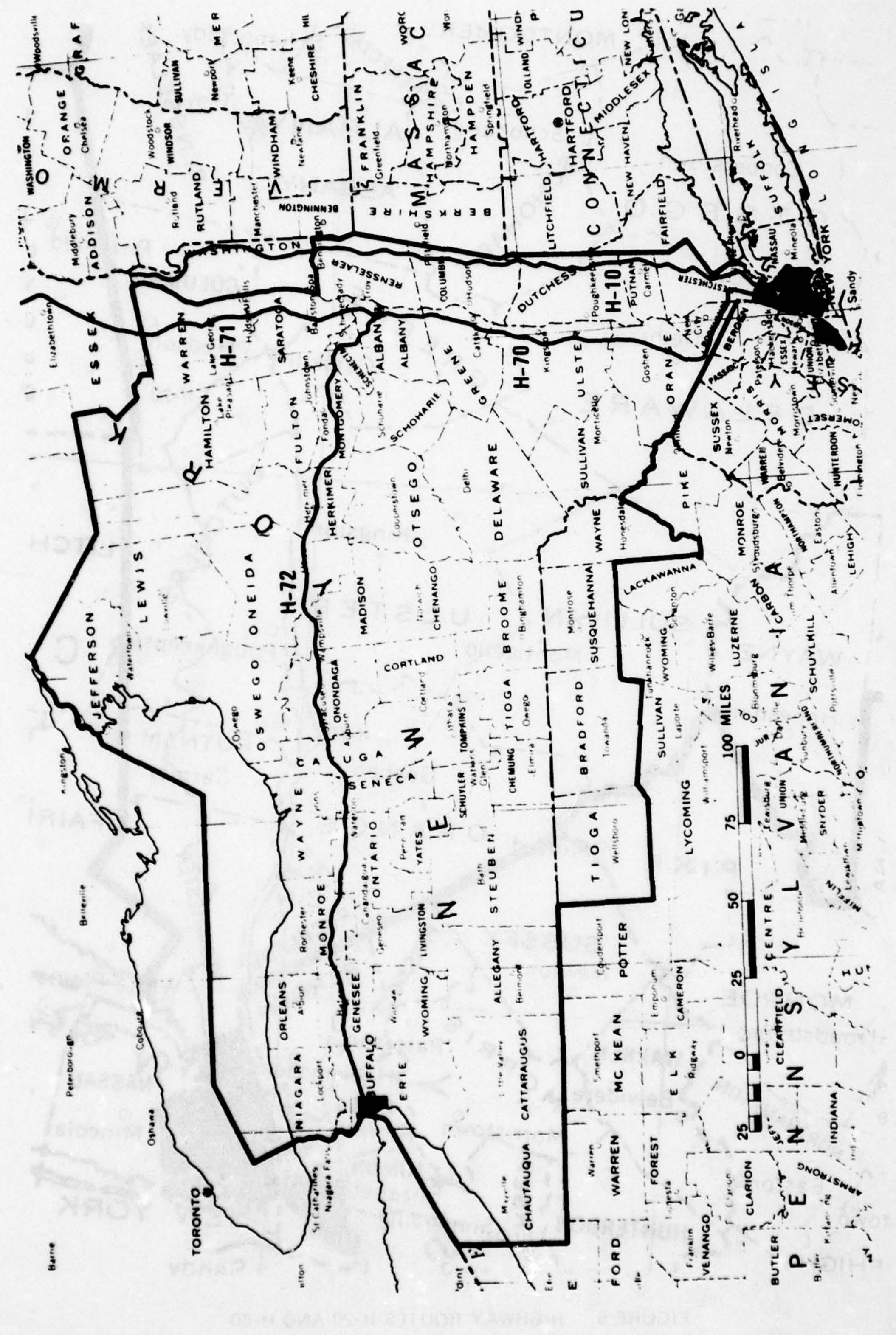

FIGURE 6 HIGHWAY ROUTES H-10 AND H-70

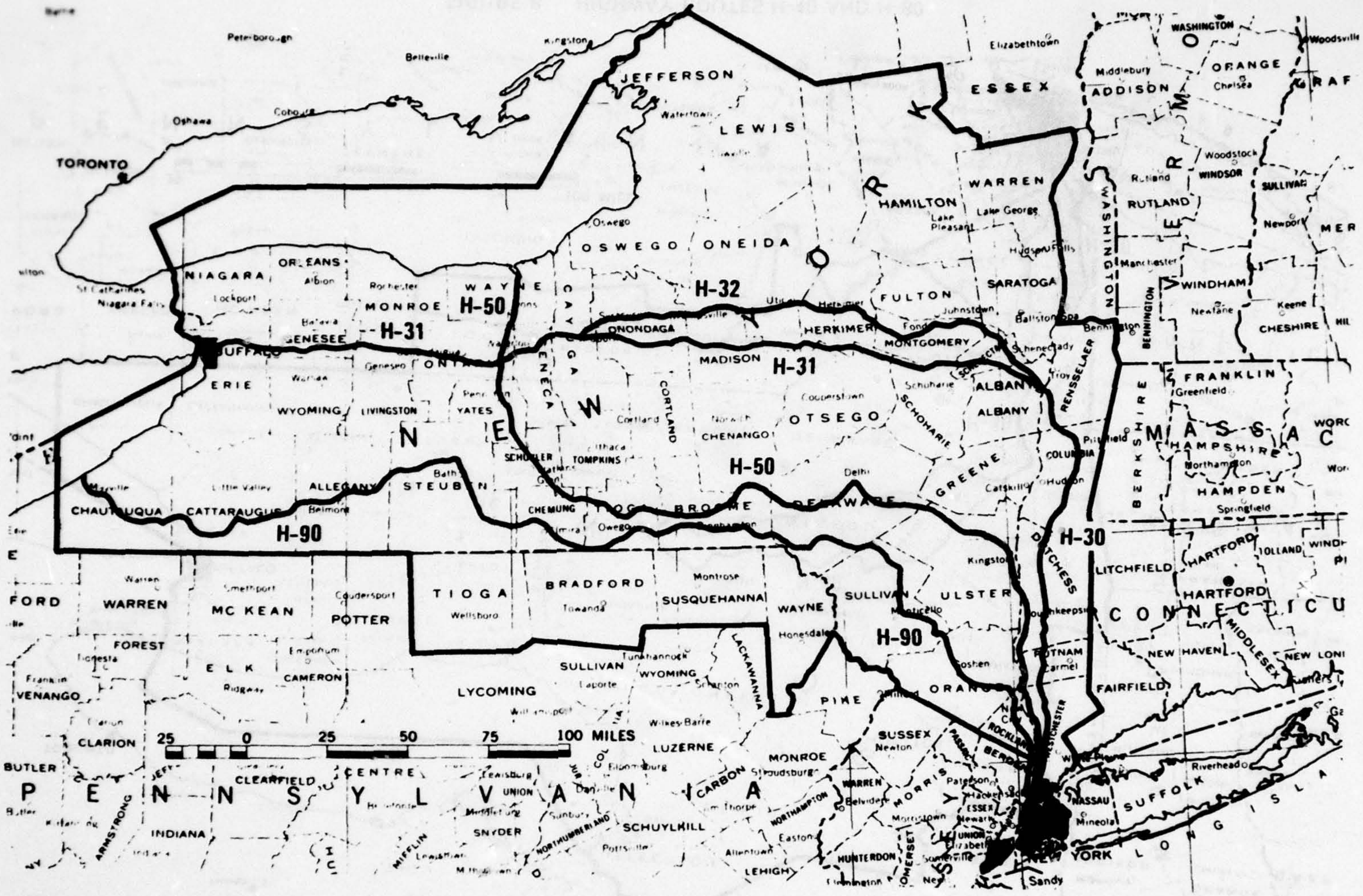

FIGURE 7 HIGHWAY ROUTES H-30, H-50, AND H-90

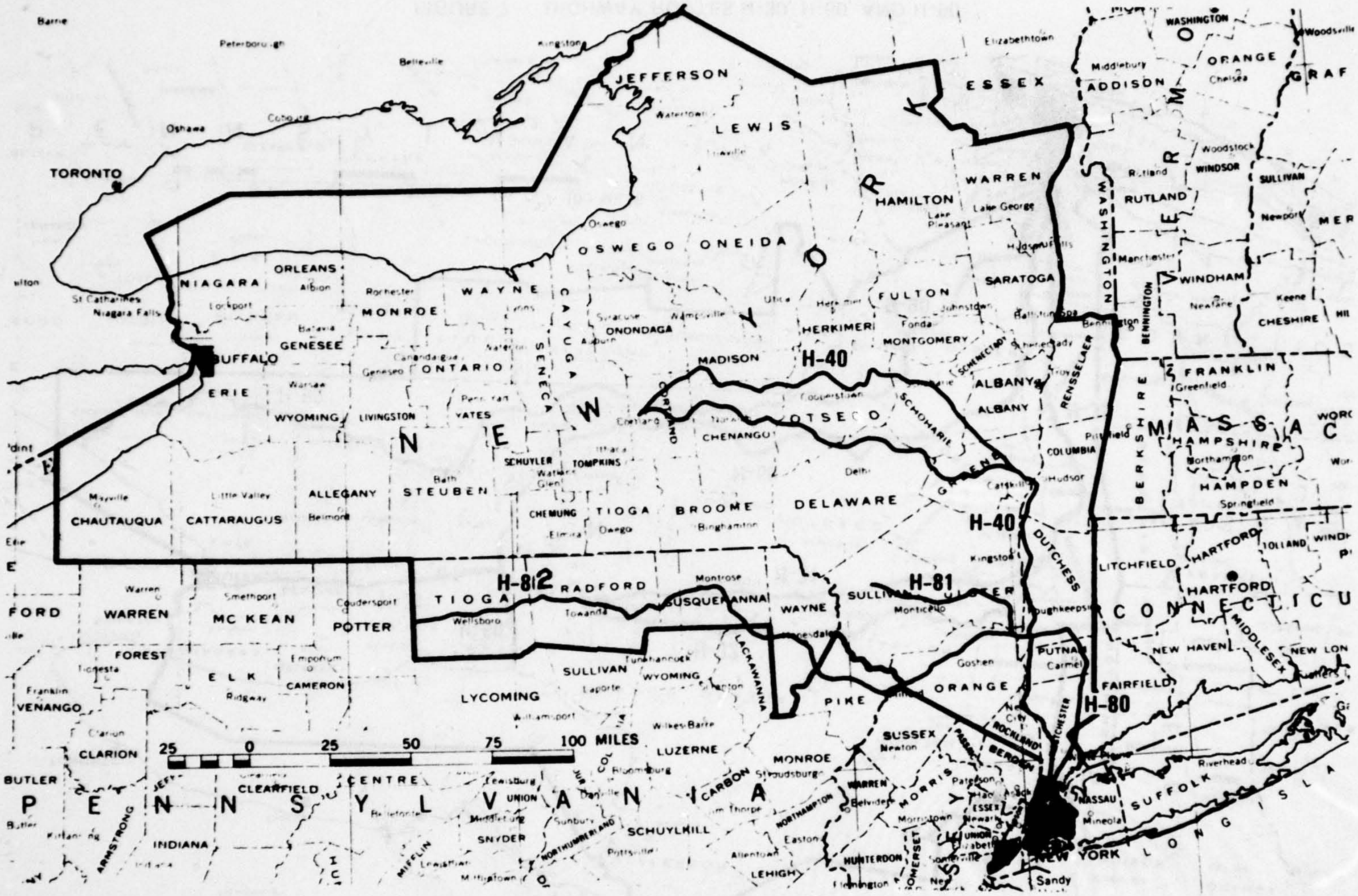

FIGURE 8 HIGHWAY ROUTES H-40 AND H-80

The majority of the route is two-lane. It is operated in the normal way as a two-way highway with all automobiles. The inbound direction accommodates emergency vehicles and returning supply vehicles for H-10, H-20, H-30, H-40, and H-50 on the east side of the Hudson River.

Route H-30

Route H-30 follows the Saw Mill River and Taconic State Parkways north to the interchange of I 90 in northern Columbia County, thence west along I 90 terminating in Albany. Route segments are:

- Saw Mill River and Taconic State Parkways from Bronx County line to northern Columbia County (intersection with I 90)
- I 90 Columbia County to Albany (Albany County).

At Albany, Route H-30 is connected to Routes H-31 and H-32.

The major portion of Route H-30 is a four-lane, partially access-controlled, divided highway. The rest of the route is a four-lane, fully access-controlled, divided highway. This route is used for all autos, one-way, outbound traffic. It is assumed that infrequent at-grade intersections on the Taconic State Parkway will be closed-off in the operation period.

Route H-31

Route H-31 is an extension of Route H-30. It uses NY 20, which runs parallel to and south of I 90 from Albany to Erie County. The route segments are:

- From I 90 in Albany use NY 85 to connect with NY 20
- NY 20 from Albany to I 90 in Erie County.

The majority of the route west of Albany is two-lane. This route is operated as a one-way, outbound highway with all automobiles.

Route H-32

Route H-32 is a second extension of H-30. It runs parallel to and north of I 90. The route segments are:

- From I 90 in Albany use NY 443 to NY 5
- NY 5 from Albany to Auburn in Cayuga County.

This route is a combination of two-lane and four-lane sections. It is operated as a one-way, outbound highway with all automobiles.

Route H-40*

Route H-40 proceeds north from the Bronx County line through Westchester, Putnam, and Dutchess Counties into Columbia County. It then runs west (crossing the Hudson River) to Cortland County, passing through Greene, Delaware, Otsego, and Chenango Counties. The route segments are:

- NY 100 Bronx County line to Fairview (Westchester County).
- NY 119 and NY 9A Fairview to Crotonville (Westchester County).
- US 9 Crotonville to Wappingers Falls (Dutchess County) via city of Peekskill and Putnam County.
- NY 9E and NY 376 Wappingers Falls to Poughkeepsie (Dutchess County).
- NY 9G Poughkeepsie to intersection of US 9 north of Rhinebeck (Dutchess County).
- US9 north of Rhinebeck to intersection of NY 23 south of Hudson (Columbia County).
- NY 23 (across the Hudson River) westward through Oneonta (Otsego County) to South Otselic (Chenango County).
- NY 26 and NY 41 South Otselic to Cortland (Cortland County).

The majority of the route is two-lane. It is operated as a one-way outbound highway with all automobiles.

Route H-50*

Route H-50 follows along the east side of the Hudson River to north of Rhinebeck, thence west and south to Binghamton. From Binghamton the route is north and terminates in Wayne County on Lake Ontario. The route segments are:

- US 9 Bronx County line to Peekskill (Westchester County)
- NY 9D Peekskill to Wappingers Falls (Dutchess County)
- US 9 Wappingers Falls to north of Rhinebeck (Dutchess County)
- US 9G, NY 199 north of Rhinebeck to north of Kingston (Ulster County) crossing the Hudson River on NY 199.
- NY 28 north of Kingston to Oneonta (Otsego County)

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*Specifications for Routes H-40, H-50 and H-70 were revised in response to comments made by reviewers of the draft final report.

- I 88 Oneonta to Binghamton (Broome County)
- NY 434 Binghamton to Owego (Tioga County)
- NY 96 Owego to Spencer (Tioga County)
- NY 224 Spencer to Montour Falls (Schuyler County)
- NY 14 Montour Falls to Sodus Point (Wayne County).

The majority of the route is two-lane. It is operated as a one-way, outbound highway with all automobiles.

Route H-60

Route H-60 parallels the Hudson River on the west, following US 9W from the George Washington Bridge to the Orange County line north of Middle Hope. It is a two-lane highway operated as a one-way, outbound highway with all automobiles.

Route H-70*

Route H-70 follows I 87 north from the Bronx County line across the Tappan Zee Bridge and to Albany on the west side of the Hudson River. The route is a six-lane freeway to Harriman in Orange County and a four-lane freeway from Harriman to Albany. The route is used for mixed traffic including automobiles making one-way trips and large vehicles (buses and trucks) making round trips. It is the main route for large vehicles and carries all of the large-vehicle traffic used for passenger service. From Bronx to Harriman the three outbound lanes carry autos and large vehicles in mixed traffic. The inbound lanes are used for two-way traffic as follows: the median lane (lane 3) carries autos outbound; the center lane (lane 2) carries no traffic and is reserved as a buffer; and the shoulder lane (lane 1) carries inbound buses, trucks, and emergency vehicles. From Harriman to Albany all four lanes are used for outbound mixed traffic. Inbound buses, trucks and emergency vehicles travel on a parallel backhaul route comprised of US 9W, from Albany to Newburgh, and NY 32 from Newburgh to Harriman. The back haul route can operate as a one-way, two-lane route, if necessary, and will accommodate traffic flows of 600 to 750 buses and large trucks per hour.

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* Specifications for Routes H-40, H-50 and H-70 were revised in response to comments made by reviewers of the draft final report.

Route H-71

Route H-71 is an extension of Route H-70. The route starts at Albany and follows I 87 north to Clinton County. The outbound lanes carry mixed traffic of automobiles and large vehicles, and the inbound lanes carry returning large vehicles and emergency vehicles.

Route H-72

Route H-72 is another extension of Route H-70. It starts at Albany and follows I 90 west to Buffalo. The route carries mixed traffic on two lanes outbound, and buses, trucks, and emergency vehicles on two lanes inbound.

Route H-80

Route H-80 starts at Bronx County line and follows Hutchinson River Parkway and I 684 to Putnam County where I 684 meets I 84. At this point the route turns west (crossing the Hudson River) and ends in Orange County. The route segments are:

- Hutchinson River Parkway, Bronx County line to White Plains (*Westchester County*).
- I 684 White Plains to intersection with I 84 near Brewster (Putnam County).
- I 84 from Brewster crossing the Hudson River to Newburgh (Orange County).

Route H-80 is a four-lane, fully controlled freeway except at the bridge on the Hudson River where the width of the bridge is 30 ft from curb to curb. (This narrow bridge is a severe bottleneck. Plans call for construction of a new bridge, but the expected completion date is unknown.) The route is operated as a one-way, outbound highway for all autos.

Route H-81

Route H-81 is an extension of Route H-80. It starts in Orange County and follows NY 32, US 44, US 209, and NY 52 to Sullivan County, where the route meets and feeds H-90. The route segments are:

- NY 32 Newburgh to Modena (Ulster County)
- US 44 Modena to intersection of US 209 near Kerhonkson (Ulster County)
- US 209 Kerhonkson to Ellenville (Ulster County)
- NY 52 Ellenville to Grossinger (Sullivan County).

This route is a two-lane highway and is operated as a one-way outbound highway with all automobiles.

Route H-82

Route H-82 is another extension of H-80. It starts on I 84 on the west side of the Hudson River and follows mainly I 84 and US 6 to northern Pennsylvania counties. The route segments are:

- I 84 Newburgh (Orange County) to the interchange with US 6 in Pike County, PA
- US 6 and I 84 to Carbondale, PA (NY 97 is used as a supplementary route).
- PA 106 Carbondale to New Milford, Susquehanna County, PA
- PA 706 New Milford to Wyalusing, Bradford County, PA
- US 6 from Wyalusing to Tioga County, PA.

Route H-82 is a four-lane, fully controlled highway on I 84. The route is assumed to be a two-lane highway from that point west. It is operated as a two-way highway for all autos on the primary route (US 6 and its connectors) and is operated as a one-way outbound highway for all autos on the supplementary route (NY 97 and its connectors). The inbound lane of US 6 is used for back-haul traffic such as emergency vehicles and returning supply vehicles.

Route H-90

Route H-90 follows the Palisades Interstate Parkway into Orange County, thence westerly on NY 17 across the southern part of New York State through Binghamton in Broome County, and terminates in Chautauqua County at the western border of the state. The route segments are:

- Palisades Interstate Parkway from George Washington Bridge to the intersection with US 6 just across the Rockland-Orange County line.
- US 6, NY 210, and NY 9 are parallel routes connecting Palisades and NY 17.
- NY 17 from Orange County to Jamestown (Chautauqua County).

The route is a four-lane, fully access-controlled highway on the Palisades Interstate Parkway and is a four-lane partially access-controlled highway on NY 17. Traffic is all outbound. The principal connection between the Parkway and NY 17 is US 6, but its narrow width presents a severe bottleneck for a distance of about six miles. NY 59 and NY 210 are used as supplementary routes to overcome this constraint. Construction of roads to provide additional capacity is highly desirable in this link.

Bottleneck Identification

It has been assumed that bottlenecks will be identified in plans and that special efforts will be made to control traffic and to prevent turning and crossing movements within the bottlenecks. Consequently, the effective capacity at the bottleneck is the full capacity computed according to the Highway Capacity Manual--it is not reduced 20% as discussed above. The evacuation routes were selected so that there are no places where two routes intersect each other (except where routes are grade separated). In cases where two routes merge and share a section of highway a check was made to be sure that the volumes of traffic remaining on the two routes could be merged without exceeding the capacity of the single highway.

As shown in Appendix A there are numerous bottlenecks along some routes, but only a few are critical in the relocation process. These could be improved by relatively small investments.

Two severe bottleneck sections and needed improvements are:

- The bridge that crosses the Hudson River on I 84 has a road width of 30 ft from curb to curb. Widening of the bridge to four lanes is planned and will be helpful.

- The connector between Palisades Interstate Parkway to NY 17 is US 6, which is a two-lane, two-way highway. A direct connection by a new four-lane freeway is desirable.

Several modifications of freeway interchange and rural at-grade intersections are assumed to have been made prior to the crisis to provide needed capacity. These modifications have not been studied in detail but it is expected that most would require relatively small investments. The modifications include widening interchange ramps, widening and channelizing at-grade intersections, and other short-length changes. Some ramp shoulders may be converted to traffic lanes for relocation traffic.

Some examples of interchanges and at-grade intersections for which detailed capacity studies are needed and where modifications may be required are as follows:

- Interchanges
  - Between I 684 and I 84 on Route H-80
  - Between I 84 and NY 97 on Route H-82
  - Between Palisades Interstate Parkway and US 6 on Route H-90
  - Between I 90 and NY 85 on Route H-31
  - Between NY 85 and US 20 on Route H-31.
- At-grade intersections
  - Between NY 17 and NY 17A on Route H-90
  - Between NY 59 and NY 17 on Route H-90.

Special studies are also needed for all freeway interchanges on highways that are to be operated as one-way outbound routes.

Backhaul Routes

Low volumes of traffic will be generated by police and other emergency vehicles and supply trucks that must make both outbound and inbound trips during the evacuation period. Highway routes were chosen so that the recirculation of this traffic is possible in all parts of the state.

Route H-20 was designed especially for recirculation traffic. The route will carry most of the back-haul traffic in Westchester, Putnam, and Dutchess Counties. Further north there are many back-haul routes including Route H-10, which will be operated as a two-way highway north of Dutchess County.

Route H-70 was also operated to include a backhaul lane for police and emergency vehicles. This route will cover most of the central New York counties. Also, many highways not fully utilized for evacuation purposes are available for backhaul traffic.

It is assumed that backhaul traffic along the southern border of the state will be carried by routes operated for two-way traffic in New Jersey near the state borders.

Highway Route Productivity

Highway route productivity is defined as the number of people to be transported by a route in a given period. Estimates of the productivity of a route are based on the assumption that automobiles carry 3.1 people on an average, and large vehicles--buses and truck-tractors and semi-trailers--carry 50 people on an average. It is further assumed that a day's productivity on each route is equivalent to 20 hours of operation at the estimated route capacity. Thus the productivity of each route for a whole day's operation is given as:

- Highways used for autos only:

  Route productivity/day = estimated hourly effective capacity x 3.1 persons per autos x 20 hours per day.

- Highways used for large vehicles only:

  Route productivity/day = estimated hourly effective capacity for large vehicles x 50 persons per vehicle x 20 hours per day.

- The productivity of highways used for mixed traffic for the number of vehicles of each type. The route productivity of two-lane highways with all autos varies from about 33,500 people per day with two-way traffic to about 134,300 people per day with one-way traffic in both lanes. (The great improvement in productivity results from the elimination of passing maneuvers.)

The productivity of freeways and expressways varies from 93,000 people per day per lane (with all auto traffic) to 750,000 persons per day per lane (with all large vehicles).

Vehicles

First Autos

In the base solution one guiding principle was to use substantially all the first autos in the New York City risk area. (Transportation of essential workers and their dependents via air was the only exception.) People who do not have access to automobiles are transported in large vehicles and by nonhighway modes. According to the feasibility study, the population in the risk area has access to 2,075,200 first autos. Each first auto is assumed to carry 3.1 persons which is near the average number of persons per occupied dwelling unit throughout the risk area. In the base solution, 1,995,400 first autos are used and 6,185,800 million persons are relocated by auto.

Large Vehicles

The number of buses, truck-tractors and semitrailers, and commercial trucks of intermediate and large sizes presently available in the risk area has been estimated. The actual number of buses in the nine counties at risk is known, but the division into capacity classes has been estimated on the basis of state and county registration statistics for trucks of all kinds and a state-level breakdown of commercial vehicles by type and weight. The total number of vehicles of each type and the number assumed to be available for crisis relocation service are given in Table 11.

Capacities

It is assumed that intercity, suburban, urban, and large school buses can carry 50 adults and children plus 2,500 lb of luggage and that intermediate buses have half that capacity. A variety of arrangements

Table 11

AVAILABILITY OF BUSES AND TRUCKS
IN NINE RISK AREA COUNTIES

	Estimated Total	Assumed Useable for Relocation Service
Buses		
Large	20,000	20,000
Intermediate	4,000	4,000
Truck-Tractors and Semitrailers	10,500	5,000
Trucks		
Intermediate (over 20,000 lb)	22,600	11,000
Small (10,000-19,900 lb)	32,700	16,000
Pickups, vans, etc. (to 9,999 lb)	173,500	0

Source: New York State Department of Motor Vehicles (1975). Allocations by sizes and estimates of numbers useable for crisis relocation by SRI.

can be made to accommodate these passengers and to carry luggage. It is known that about 20% of the passengers will be under the age of 12 and can double up in seats. Therefore, only 9 seats are required per 10 passengers. Intercity buses have luggage space below the passenger deck and about 45 seats. Most suburban and urban buses have 40-ft bodies and about 50 seats. Baggage can be carried in some seats and in aisles. Large school buses typically have seats for about 65 students of varying ages. Again, luggage can be carried in seats and aisles.

Tractor-trucks and semitrailers are assumed to carry 50 passengers plus luggage--the same number of passengers as a large bus. A 40-ft semitrailer has about 300 sq ft of floor space and will provide about 6 sq ft of space per passenger and luggage.

Small buses and intermediate trucks with 20-ft cargo boxes are assumed to have half the capacity of a large bus or tractor-truck and trailer--that is, 25 passengers and luggage.

Productivity

Buses and trucks can achieve their best productivity by making several round trips. Therefore, cycle times must be computed. It was assumed that the operating speeds of vehicles on highways are: 40 mph on controlled highways, 35 mph on uncontrolled highways, and 30 mph on feeder and distribution ramps. However, in the base solution only freeways are used for large vehicles in passenger service. The routes are H-70 to Albany (I 87) and H-72 west toward Buffalo (I 90).

In the base solution it was estimated that a flow of approximately 586 large vehicles per hour will be needed to transport 1,758,300 million carless persons in a three-day period. (Other carless persons are transported by nonhighway modes.)

The number of large vehicles needed to maintain a flow of 586 vehicles per hour was estimated for various distances between origins and destinations. In calculating the number of large vehicles required, it was assumed that the travel speed of large vehicles is 40 mph on the freeway(s) and 30 mph on local feeder and distribution routes in risk and host areas. It was also assumed that the travel distance of large vehicles to and from the freeway(s) is 15 miles at each end. The total standing or idle time in one round trip was assumed to vary from one hour for a 100-mile trip to three hours for a 300-mile trip. This time is used for passenger loading, unloading, rest stops, and other delays in the duty cycle.

Numbers Required

Maintenance of the flow rate of 586 vehicles per hour for an average of 20 hours each day for three days will require dispatching 35,170 loaded vehicles. It is assumed that each vehicle can be kept in the duty cycle an average of 45 hours during three days and will be out of service an average of 27 hours in three days. Thus if average cycle time per round trip were 9 hours, the average vehicle would make five deliveries and the required fleet would contain 7,034 vehicles. Vehicle requirements for distances of 100 to 300 miles are presented in Table 12.

Table 12

NUMBER OF LARGE VEHICLES NEEDED

Miles	Round Trip Travel Time on Freeway (hr)	Round Trip Travel Time on Local Routes (hr)	Standing Time* (hr)	Cycle Time (hr)	Average Number of Outbound Trips in Three Days†	Total Number of Vehicles Needed‡
100	4.25	1.0	1.0	6.25	7.2	4,880
150	6.75	1.0	1.5	9.25	4.86	7,240
200	9.25	1.0	2.0	12.25	3.67	9,580
250	11.75	1.00	2.5	15.25	2.94	11,960
300	14.25	1.00	3.0	18.25	2.46	14,300

*Includes loading, unloading, rest time for drivers, and the like.

†Assumes vehicles are in duty cycle for 45 hr in three days.

‡Assumes that 35,170 vehicles must be dispatched in three days.

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In the base solution the average travel distance for persons transported in buses and trucks was about 100 miles and the number of large vehicles required was about 4,850. As indicated above, it appears that there are about 20,000 large buses and 5,000 truck-tractor and semitrailer sets available for relocation service. The supply of buses is more than adequate, and use of truck-tractors and semitrailers for main-line passenger movements can be avoided entirely.

Fuel and Service

The feasibility study concluded that all automobiles needed for crisis relocation travel can be fueled and serviced within risk areas before starting relocation journeys without overloading service facilities and exhausting fuel supplies. This is possible because nonessential travel will be prohibited and a substantial fraction of the vehicles normally fueled and serviced each day will remain idle. Fuel tanks of automobiles to be used for relocation can be and should be filled before the start of the relocation trip. Most autos have a range of at least 250 miles and some can travel up to 350 miles on a full tank.

In the base solution it was found that 20% of the autos used would travel 250 miles or more, and some would travel 390 miles. These distances are great enough to make enroute fueling necessary for some autos. The problem of supplying this fuel has not been analyzed in this research. However, it appears that less than 20% of the autos (400,000 vehicles) will require refueling. The average distance of travel beyond the range on the initial fill will probably not exceed 50 miles. At 12.5 miles per gallon the total fueling requirement is about 1.6 million gallons. Delivery of this fuel plus a 50% oversupply allowance will require about 350 tanker trips via highway. Fuel does not have to be delivered from New York City but from facilities for bulk fuel distribution located along the Hudson River and on a fuel pipeline extending across New York State. This appears to be feasible. However, careful preparations must be made to satisfy the need for gasoline. The consequences of a general shortage of fuel along relocation routes would be highly disruptive.

Most large vehicles--buses and truck-tractors--use diesel fuel, but some buses use gasoline. Special arrangements will have to be made to refuel large vehicles in the risk area and at several points along routes H-70 and H-72.

Road service vehicles will be required along all routes to remove stalled vehicles from traffic lanes as quickly as possible. Existing road service vehicles will have to be assigned to duty stations. Improvised road service vehicles, such as pick-up trucks and farm tractors, will have to be added to the fleet.

Only a small fraction of the auto fleet should experience breakdowns--perhaps 1% to 2%. Most stalled vehicles will not be reparable and will not be able to continue beyond the breakdown point. Passengers can be hosted near the point of breakdown or can be collected in large vehicles, placed in the traffic stream for the purpose, and transported to more distant host areas.

VII ALLOCATION AND TRANSPORTATION ANALYSES

This section describes the analytical procedure employed to allocate the population of each risk area in the New York planning area among the host counties of the planning area. It also describes and illustrates the analytical procedures used to ensure that transportation capabilities are effectively matched with transportation needs.

Base Solution and Feasibility Study

The allocation of population and the utilization of transportation described in this chapter is called the "base solution." It uses the same planning area boundaries and hosting criteria as the feasibility study, relocates all carless persons in three days, utilizes all first automobiles,* and completes the relocation in 3.3 days. It also makes provisions for daily round trips by 906,000 essential workers--8% of the risk population.

The base solution is the final product of a series of trials. Each trial included an allocation of population, a transportation analysis, and an evaluation of results. As expected, the results of the first trial were unsatisfactory but revealed avenues for improvements. Subsequent trials incorporated different allocations of population and different schemes for structuring transportation routes and exploiting transportation resources. The base solution described below represents the most satisfactory results obtained from the series of trials and is believed to provide the shortest redeployment period obtainable, under the stated criteria, until large efforts can be expended by planners to improve input data and analytical methods.

Alternative solutions based on assumed changes in criteria are described in Section VIII.

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*Except those displaced by use of air travel for some essential workers.

Allocation Procedure

The allocation of the population of the risk counties to appropriate host counties is an essential step in the analysis of crisis relocation. The allocation process used in this study is considerably more complex than that used in the feasibility study and approaches the level of detail that will be needed as the foundation of actual plans.

The principal complication added to the allocation process in this study arises from the necessity to constrain and tailor the hypothetical movements of travelers to the available highway and nonhighway routes and their capacities. In the feasibility study, tests of highway capacities were made at cordon lines judged to be limiting. In this study highway routes are defined and analyzed individually from the risk area to each host county. In the feasibility study, travel by nonhighway modes was evaluated in general terms, while in this analysis, specific and detailed allocations were made. Four population groups, defined later, are recognized. All members of each group in each risk county are assigned to host counties and to particular transportation modes and routes.

The allocation procedure used in this analysis has certain common characteristics with the procedure used in the feasibility study and reflected in the draft planning guidance provided to DCPA as part of the earlier work. These commonalities are summarized below.

Initial trials were based on the planning area assigned to New York City in the feasibility study. As shown in Figure 1 the area comprises all of the New York State except five northern counties--Washington, Essex, Clinton, Franklin, and St. Lawrence--which are assigned to New England, plus four counties in northeastern Pennsylvania--Wayne, Susquehanna, Bradford, and Tioga.

The definition of the population at risk is identical with that used in the feasibility study and reflects the DCPA risk criteria. The planning area contains a number of outlying risk areas, notably Albany, Syracuse, Rochester, Buffalo, and several smaller areas. These must be accounted for in the allocation, as they would be relocating too. Outlying risk counties are given priority in the use of hosting space within

their own boundaries. This is not the case with Rockland and Westchester Counties in the New York Metropolitan area, as the hosting capacities of those counties are urgently needed to house essential workers and their dependents. Table 13 shows the key characteristics of those outlying risk counties that must relocate some or all of their population beyond their boundaries. Equivalent data for counties in the New York metropolitan area are shown in Table 1.

As in the feasibility study, the hosting capacity of counties not at risk is assumed to be five times the resident population. Sufficient data from host area surveys of congregate-care space were not available to permit more accurate apportionment of hosting capacity. This limitation is not expected to affect the significance of the results of the analysis to any great extent.

Potential fallout risk is crucial in defining the planning area. A number of localities in Suffolk County not subject to blast risk were not evacuated but were not used for hosting because of high fallout risk. This is the only instance of restricted hosting in the planning area. However, similar areas exist in Monmouth and Ocean Counties in New Jersey south of New York City.

Northeast New Jersey is assumed to move west into Pennsylvania in an operation planned separately from that of New York. The only interfaces between the New York and New Jersey plans were found to be the use by New York of two rail lines, short highway segments near the Hudson River and New York-New Jersey boundary, and partial use of one air field. In some alternatives, it was assumed that hosting space and highway capacity in New Jersey was available to New York. Selection of these options would require joint planning of the New York City and northeastern New Jersey relocations.

All population data used in this analysis are from the 1970 census. However, the area under consideration is not one in which rapid population changes have occurred.

The underlying allocation procedure used in this analysis is the "20-percent slice" method used and described in the feasibility analysis.

Table 13

SUMMARY OF INPUT DATA: POPULATION AND ACCESS TO FIRST AUTOS
IN OUTLYING RISK COUNTIES

	Albany	Rensselaer	Schenectady	Onondaga	Erie	Monroe
Total population	286,742	152,510	161,078	472,835	1,113,491	711,917
Population at risk	279,113	128,698	157,278	472,835	985,285	608,446
Essential workers	55,823	25,740	31,456	94,567	197,057	121,689
General public	223,290	102,958	135,822	378,268	788,288	486,756
Percentage with access to autos	78.8%	80.6%	84.5%	88.3%	80.0%	84.7%

The procedure was designed to equalize, approximately, the average and maximum travel distances via highways among the counties in the New York metropolitan area. The method was not used for the other risk counties in New York state. Relocatees from these counties were generally assigned to neighboring counties in the direction <u>away</u> from New York City and <u>away</u> from the major routes that were identified for use by the New York metropolitan area risk population.

Population Groups

The risk population of each risk county was subdivided into four population groups. Tables 1 and 13 indicate that the population at risk is subdivided into two groups--essential workers and their dependents (EW) and the general public (GP). EWs make up 8% of the population and, with their dependents, constitute 20% of the population. This percentage was used in all trials although it is thought to be somewhat high. The remaining 80% are classed as GP. EWs were assigned to hosting space from which they could commute to and from the risk area. The GP was allocated hosting space after essential workers had been assigned.

Each of the basic groups was further subdivided into those with first autos and those without. The 1970 census data on households with one or more autos is shown for each county in Tables 1 and 13. In each county, this percentage was applied to both EWs and GP. In the allocation procedure, the four groups were coded EWA (essential workers and dependents with autos); EWB (essential workers and dependents without autos); GPA (general public with autos); and GPB (general public without autos).

In most trials, it was assumed that GPAs would use their private autos. EWBs and GPBs had to be transported by nonhighway modes--air, rail, water, and buses. In the case of EWAs, the means of commuting had to be considered. Most EWAs used their autos, but it was assumed that they could be assigned to other modes if it was advantageous for commuting. For example, air transportation was used for EWAs in Suffolk County, Long Island, to avoid the need for vehicular commuting throughout the length of the New York metropolitan area.

The definition of EWs in this analysis, as in the feasibility study, is a static one. The actual numbers can only be determined by detailed planning and are likely to vary from county to county. Many EWs in New York City are known to live in New Jersey and Connecticut as well as in Suffolk, Nassau, Westchester, and Rockland Counties. Attention to this problem will be needed in actual crisis relocation planning.

The order of allocation was to assign transportation and hosting locations to essential workers and their dependents--EWAs and EWBs--first, then to assign transportation and hosting locations to GPBs, and finally to allocate routes and hosting space to GPAs. Only in the latter case was it important to employ the 20-percent slice method. For GPAs, only 20% were allocated routes and hosting space initially, beginning with Richmond County (Staten Island), the furthest removed from potential hosting space, and treating each risk county in turn. The procedure then returned to Richmond County to allocate the second 20-percent slice. The iterations were continued until all GPAs were accounted for. If this procedure had not been used, Richmond County might have occupied Dutchess County, a distance of about 100 miles, whereas Rockland County might have been assigned to Jefferson County, a distance of about 350 miles.

Allocation and Transportation Priorities

First priority was given to the allocation of EWs. Air and rail routes suitable for commuting were assigned to EWBs. In one case, Suffolk County, air transportation was also used for essential workers and dependents having access to automobiles to avoid the need for long and time-consuming commuter trips via auto.

The remaining air and rail transportation and all water transportation was then allocated to members of the general public without access to autos. Attention is called to the fact that each air and rail route used for commuting also carries some members of the general public. This is necessary because essential workers make up 40% of the essential worker and dependent group while the daily commuting volumes on each

route are substantially less than 40% of the route's production during the three-day relocation period.

Thereafter all of the remaining general public without autos were allocated to counties along a single, special, highway route and were transported in buses (but truck-tractors and semitrailers can be used if necessary). In the base solution, the scale of this operation was adjusted to complete the relocation of the general public without autos in a three-day period.

The last stage of the allocation process accounted for the movement of general public with automobiles using all special highway capacity not previously committed to EWAs and to large vehicles. This operation was continued until all of the remaining people with access to first autos (and the last residents of the risk area) had been relocated. In the base solution the last travel parties in autos would begin their relocation journeys at 3.3 days.

Production of Special Transportation Routes

The production of each special transportation route has been estimated for relocation operations and commuting services for the base solution. The production data and certain route characteristics for each transportation modes are presented in Tables 14-17.

Production data for air, rail, and water and for buses on highways are estimated for a three-day relocation operation. Production data for autos include 3.3 days, which is the period required to complete the operation in the base solution. The production estimate for a route is obtained by multiplying the effective bottleneck capacity by a production factor of 204.6. The production factor is derived as follows:

> 3.1 persons per auto x 20 hours per day of effective route operation x 3.3 days of relocation movement = 204.6.

Exceptions to this procedure are contained in parentheses. The term of the relocation operation--3.3 days--was determined by repeated trials as described below.

Table 14

PRODUCTION OF SPECIAL AIR ROUTES

Designator	Risk Airport	Host Airport	Deliveries per Day	Daily Production in Commuter Service	Three-Day Production in Relocation Service
A-1	JFK	Niagara	120	N/A	132,000
A-2	JFK	Buffalo	240	N/A	216,000
A-3	JFK	Rochester	180	N/A	138,000
A-4	JFK	Syracuse	170	N/A	153,000
A-5	LaGuardia	Syracuse	10	N/A	9,000
A-6	LaGuardia	Stewart	180	41,400	162,000
A-7	LaGuardia	Albany	120	N/A	61,200
A-8	LaGuardia	Erie, PA	120	N/A	43,200
A-9	LaGuardia	Bradford, PA	120	N/A	43,200
A-10	Islip	Ithaca	120	10,800	43,200
A-11	Islip	Williamsport, PA	30	N/A	10,800
A-12	Calverton	Williamsport, PA	90	N/A	32,400
A-13	Calverton	Elmira	60	5,400	21,600
A-14	Westhampton	Elmira	60	5,400	21,600
A-15	Westhampton	Binghamton	90	8,100	32,400
A-16	White Plains	Binghamton	30	2,700	10,800
A-17	White Plains	Utica	120	10,800	43,200
A-18	Newark	Scranton	120	10,800	43,200
	Total		1,980	95,400	1,215,800

Table 15

PRODUCTION OF SPECIAL RAIL ROUTES

Designator	Name	Origin	Destination	Persons Relocated in Three Days	Essential Workers Transported Daily (Round Trips)
Within the risk area					
R-1a	New Haven	Grand Central Terminal	Westchester	540,000	144,000
R-1b	New Haven	Penn Station	Westchester	270,000	72,000
R-2b	Harlem	Grand Central Terminal	Westchester	360,000	96,000
Subtotal				1,170,000	312,000
To near host areas					
R-2a	Harlem	Grand Central Terminal	Westchester/Putnam	180,000	48,000
R-3a	Hudson	Grand Central Terminal	Westchester	360,000	96,000
R-4	Port Jervis	Hoboken	Rockland/Orange	180,000	48,000
Subtotal				720,000	192,000
To distant host areas					
R-3b	Hudson-Buffalo	Grand Central Terminal	South or west of Albany	180,000	48,000*
R-5	Westshore-Buffalo	Hoboken	South or west of Albany	300,000	Zero
R-6	Binghamton West	Hoboken	Binghamton and West	180,000	Zero
Subtotal				660,000	48,000
Total				2,550,000	552,000

*Commuting from near host areas.

Table 16

PRODUCTION OF HUDSON RIVER ROUTE

Host County	Persons Relocated in Three Days
Saratoga (via Albany and Troy)	75,000
Columbia	75,000
Greene	50,000
Dutchess	25,000
Ulster	25,000
Orange	50,000
Total	300,000

Table 17

PRODUCTION OF SPECIAL HIGHWAY ROUTES

Route	Effective Bottleneck Capacities (Autos/Hr/Route)	Bottleneck County	Persons Relocated in 3.3 Days
H-10	1,870	Putnam	382.6
	1,630	Dutchess	333.5
	1,560	Columbia	319.2
H-20	540-100	Dutchess	110.5
H-30	4,920	All	1,006.6
H-31	2,130	Albany	435.8
	2,090	Herkimer	427.6
H-32	2,220	Schenectady	454.2
	1,640	Montgomery	335.5
H-40	2,130	Putnam	435.8
H-50	1,870	Putnam	382.6
	1,800	Dutchess	368.3
	1,620	Wayne	331.5
H-60	2,040	Rockland	417.4
H-70	6,000	All	1,226.6 (1,009.5)*
H-71	3,000	All	613.8
H-72	3,000	All	613.8 (583.4)*
H-80	6,000	Dutchess	1,227.6
H-81	2,220	Dutchess/Orange†	454.2
	2,160	Orange	441.9 (414.7)‡
H-82	2,400	Susquehanna (PA)	491.0
	1,600	Bradford (PA)	327.4
H-90	6,000	Orange	1,227.6

*Net auto production after allowing for buses.

†Bottleneck occurs at Hudson River Bridge.

‡Production that can be fed to H-90.

The Base Solution

The base solution presented below accounts for the relocation of the population at risk in the New York metropolitan area in 3.3 days and for the transportation of essential workers each day to and from jobs in the risk area. The base solution is presented in detail for two purposes. The presentation illustrates the analysis procedures for the benefit of planners who may conduct similar analyses. It also presents the results of the last and most refined of a series of trial solutions conducted by SRI and addressed to the problems defined in Section II.

The procedure used in the allocation of the population from risk to host counties and for the assignment of population groups to transportation modes and routes involves the use of several work sheets and data files including the risk populations and the hosting capacities of each county, locations of each special transportation route together with production estimates, and a sequence of analytical steps recorded in a form which has been named the "move table."

The move table (see Table 18) is a running record of population allocations and transportation assignments. Each line of the table records the allocation and transportation of a group of people specified as follows:

- Risk county--trip origin
- Population group
  - Essential workers and dependents or general public
  - Access to first auto or carless
- Number of persons
- Mode of travel and route
- Host county--trip destination

Each line of the table also contains a record of three amounts called "residuals"--the number of persons in the group remaining after the move, the amount of unassigned production remaining for the route, and the amount of unallocated hosting capacity remaining in the host county. The number of persons in a move is always determined by a specific limit or constraint, such as exhausting the hosting capacity of a county or

Table 18

BASE SOLUTION MOVE TABLE

Move	Risk County	Population Group	Number Moved (000s)	Group Residual (000s)	Route Designators	Route Residuals (000s)	Host County	Hosting Residual (000s)
1	Suffolk	EWA	148.0	49.6	In-county	N/A	Suffolk	X
2	Westchester	EWA	124.0	X	"	"	Westchester	593.7
3	Westchester	EWB	26.1	X	"	"	Westchester	567.6
4	Rockland	EWA	34.8	X	"	"	Rockland	155.3
5	Rockland	EWB	3.5	X	"	"	Rockland	151.8
6	Suffolk	EWB	13.5	1.2	A-13	8.1	Chemung	494.2
7	Suffolk	GPB	8.1	50.5	A-13	X	Chemung	486.1
8	Suffolk	EWB	1.2	X	A-14	12.3/8.1	Chemung	484.9
9	Suffolk	EWA	12.3	37.3	A-14	8.1	Chemung	472.6
10	Suffolk	GPB	8.1	42.4	A-14	X	Chemung	464.5
11	Suffolk	EWA	20.2	17.1	A-15	12.2	Broome	540.8
12	Suffolk	GPB	12.2	30.2	A-15	X	Broome	528.6
13	Suffolk	EWA	17.1	X	A-10	9.9/16.2	Tompkins	368.2
14	Nassau	EWB	9.9	13.8	A-10	16.2	Tompkins	358.3
15	Nassau	GPB	16.2	78.7	A-10	X	Tompkins	342.1
16	Nassau	EWB	13.8	X	A-6	89.7/58.5	Orange	1094.5
17	Queens	EWB	89.7	55.0	A-6	58.5	Orange	1004.8
18	Queens	GPB	58.5	520.2	A-6	X	Orange	946.3
19	Bronx	EWB	6.8	176.9	A-16	4.0	Broome	521.8
20	Bronx	GPB	4.0	730.7	A-16	X	Broome	517.8
21	Bronx	EWB	27.0	149.9	A-17	16.2	Oneida	37.7
22	Bronx	GPB	16.2	714.5	A-17	X	Oneida	21.5
23	Richmond	EWB	11.8	X	A-18	15.2/16.2	Susquehanna,PA	159.9
24	Richmond	EWA	15.2	32.1	A-18	16.2	Susquehanna,PA	144.7
25	Richmond	GPB	16.2	30.8	A-18	X	Susquehanna,PA	128.5
26	Suffolk	GPB	30.2	X	A-12	2.2	Tioga, PA	168.3
27	Nassau	GPB	2.2	76.5	A-12	X	Tioga, PA	166.1
28	Kings	GPB	95.4	1122.3	A-1	36.6	Orleans	91.1
29	Kings	GPB	36.6	1085.7	A-1	X	Genessee	257.0
30	Kings	GPB	216.0	869.7	A-2	X	Genessee	41.0
31	Kings	GPB	138.0	731.7	A-3	X	Monroe	379.4
32	Kings	GPB	153.0	578.7	A-4	X	Oswego	235.8

Table 18 (Continued)

Move	Risk County	Population Group	Number Moved (000s)	Group Residual (000s)	Route Designators	Route Residuals (000s)	Host County	Hosting Residual (000s)
33	Queens	GPB	9.0	511.2	A-5	X	Oswego	226.8
34	Queens	GPB	61.2	450.0	A-7	X	Saratoga	334.2
35	Queens	GPB	43.2	406.8	A-8	X	Chautauqua	693.3
36	Queens	GPB	43.2	363.6	A-9	X	Bradford, PA	246.6
37	Nassau	GPB	10.8	65.7	A-11	X	Tioga, PA	157.6
38	New York	EWB	120.0	121.7	R-4	60.0	Orange	826.3
39	New York	GPB	60.0	906.6	R-4	X	Orange	766.3
40	New York	EWB	120.0	1.7	R-2a	60.0	Westchester	447.6
41	New York	GPB	60.0	846.6	R-2a	X	Putnam	223.5
42	New York	EWB	1.7	X	R-3a	358.3	Westchester	445.9
43	Queens	EWB	55.0	X	R-3a	303.3	Westchester	390.9
44	Kings	EWB	303.3	1.1	R-3a*	X	Westchester	87.6
45	Kings	EWB	1.1	X	R-2b	238.9	Westchester	86.5
46	Bronx	EWB	86.5	63.4	R-2b	152.4	Westchester	X
47	Bronx	EWB	63.4	X	R-2b†	89.0	Putnam	160.1
48	New York	GPB	300.0	546.6	R-5	X	Cayuga	87.2
49	New York	GPB	180.0	366.6	R-6	X	Steuben	317.7
50	Nassau	GPB	65.7	X	R-3b	114.3	Cayuga	21.1
51	Kings	GPB	21.5	557.2	R-3b	92.8	Cayuga	X
52	Kings	GPB	92.8	464.4	R-3b	X	Tompkins	249.3
53	Richmond	EWA	32.1	X	H-90	1195.5	Rockland	119.7
54	Nassau	EWA	119.7	142.3	H-90	1075.8	Rockland	X
55	Nassau	EWA	142.3	X	H-10/H-80‡	333.5/1134.4	Putnam	17.8
56	Kings	EWA	17.8	198.2	H-80	1116.6	Putnam	X
57	Kings	EWA	198.2	X	H-80	918.4	Dutchess	913.3
58	Queens	EWA	252.8	X	H-80	665.6	Dutchess	660.5
59	New York	EWA	66.2	X	H-80	599.4	Dutchess	594.3
60	Bronx	EWA	110.7	X	H-20	X	Dutchess	483.6

* Assumes that equipment from R-3b will assist in commuting after three days.
† EWBs assigned to R-2b must be bused from N. White Plains to host space in Westchester and Putnam.
‡ 49.1 assigned to H-10 to take advantage of Putnam only production differential (see Table 17). Remaining 93.2 assigned to H-80.

Table 18 (Continued)

Move	Risk County	Population Group	Number Moved (000s)	Group Residual (000s)	Route Designators	Route Residuals (000s)	Host County	Hosting Residual (000s)
61	Albany	EWB	11.8	X	In-county	N/A	Albany	26.3
62	Albany	EWA	26.3	17.7	"	"	Albany	X
63	Albany	EWA	17.7	X	Local	"	Saratoga	316.5
64	Rensselaer	EWB	5.0	X	In-county	"	Rensselaer	114.1
65	Rensselaer	EWA	20.7	X	"	"	Rensselaer	93.4
66	Rensselaer	GPB	20.0	X	"	"	Rensselaer	73.4
67	Rensselaer	GPA	73.4	9.6	"	"	Rensselaer	X
68	Schenectady	EWB	4.9	X	"	"	Schenectady	14.1
69	Schenectady	EWA	14.1	12.5	"	"	Schenectady	X
70	Schenectady	EWA	12.5	X	Local	"	Saratoga	304.0
71	Onondaga	EWB	15.8	X	"	"	Oswego	211.0
72	Onondaga	EWA	78.8	X	"	"	Oswego	132.2
73	Monroe	EWB	18.6	X	In-county	"	Monroe	360.8
74	Monroe	EWA	103.1	X	"	"	Monroe	257.7
75	Monroe	GPB	74.5	X	"	"	Monroe	183.2
76	Monroe	GPA	183.2	229.1	"	"	Monroe	X
77	Erie	EWB	39.4	X	"	"	Erie	601.6
78	Erie	EWA	157.6	X	"	"	Erie	440.0
79	Erie	GPB	157.7	X	"	"	Erie	286.3
80	Erie	GPA	286.3	344.3	"	"	Erie	X
81	New York	GPB	75.0	291.6	Water	X	Saratoga	229.0
82	New York	GPB	75.0	216.6	"	X	Columbia	182.6
83	New York	GPB	50.0	166.6	"	X	Greene	115.7
84	New York	GPB	25.0	141.6	"	X	Dutchess	458.6
85	New York	GPB	25.0	116.6	"	X	Ulster	681.2
86	New York	GPB	50.0	66.6	"	X	Orange	716.3
87	Richmond	GPB	30.8	X	H-70*	Bus and Truck	Orange	685.5
88	Kings	GPB	464.4	X	H-70	"	Orange	221.1
89	Queens	GPB	221.1	142.5	H-70	"	Orange	X
90	New York	GPB	66.6	X	H-70	"	Ulster	614.6
91	Bronx	GPB	614.6	99.9	H-70	"	Ulster	X
92	Westchester	GPB	104.5	X	H-70	"	Greene	11.2
93	Rockland	GPB	11.2	2.9	H-70	"	Greene	X
94	Queens	GPB	142.5	X	H-70/H-72	"	Montgomery	136.7

*The total numbers of buses traveling H-70 and H-72 have been deducted from the auto production in Table 17.

Table 18 (Continued)

Move	Risk County	Population Group	Number Moved (000s)	Group Residual (000s)	Route Designators	Route Residuals (000s)	Host County	Hosting Residual (000s)
95	Bronx	GPB	99.9	X	H-70/H-72	N/A	Montgomery	36.8
96	Rockland	GPB	2.9	X	"	"	Montgomery	33.9
97	Richmond	GPA	37.9	151.4	H-10	295.6	Dutchess	420.7
98	Suffolk	GPA	158.1	632.4	H-80	441.3	Dutchess	262.6
99	Nassau	GPA	209.6	838.6	H-10	86.0	Dutchess	53.0
100	Kings	GPA	53.0	810.9	H-10	33.0	Dutchess	X
101	Kings	GPA	33.0	777.9	H-10	X	Columbia	149.6
102	Kings	GPA	86.8	691.1	H-40	349.0	Columbia	62.8
103	Queens	GPA	62.8	948.3	H-40	286.2	Columbia	X
104	Queens	GPA	139.4	808.9	H-90	936.4	Sullivan	123.5
105	New York	GPA	52.9	211.8	H-90	883.5	Sullivan	70.6
106	Bronx	GPA	70.6	372.1	H-90	812.9	Sullivan	X
107	Bronx	GPA	17.9	354.2	H-90	795.0	Delaware	205.7
108	Westchester	GPA	99.2	397.0	H-80/H-81	342.1/315.5	Delaware	106.5
109	Rockland	GPA	27.9	111.5	H-90	767.1	Delaware	78.6
110	Richmond	GPA	37.9	113.5	H-90	729.2	Delaware	40.7
111	Suffolk	GPA	40.7	591.7	H-90	688.5	Delaware	X
112	Suffolk	GPA	116.4	475.3	H-60/H-82	301.0/374.6	Wayne, PA	X
113	Suffolk	GPA	1.0	474.3	H-40	285.2	Schoharie	122.8
114	Nassau	GPA	122.8	715.8	H-40	162.4	Schoharie	X
115	Nassau	GPA	86.8	629.0	H-50	281.5	Otsego	194.1
116	Kings	GPA	172.8	518.3	H-50	108.7	Otsego	21.3
117	Queens	GPA	202.2	606.7	H-70/H-71	807.3/411.6	Saratoga	26.8
118	New York	GPA	52.9	158.9	H-90	635.6	Broome	464.9
119	Bronx	GPA	26.8	327.4	H-70/H-71	780.5/384.8	Saratoga	X
120	Bronx	GPA	21.3	306.1	H-50	87.4	Otsego	X
121	Bronx	GPA	40.4	265.7	H-90	595.2	Broome	424.5
122	Westchester	GPA	99.2	297.8	H-80/H-82	242.9/275.4	Susquehanna, PA	29.3
123	Rockland	GPA	27.9	83.6	H-90	567.3	Broome	396.6
124	Richmond	GPA	37.9	75.6	H-90	529.4	Broome	358.7
125	Suffolk	GPA	33.9	440.4	H-70/H-32	746.6/335.5	Montgomery	X
126	Suffolk	GPA	124.2	316.2	H-90	405.2	Broome	234.5
127	Nassau	GPA	209.6	419.4	H-90	195.6	Broome	24.9
128	Kings	GPA	24.9	493.4	H-90	170.7	Broome	X

Table 18 (Continued)

Move	Risk County	Population Group	Number Moved (000s)	Group Residual (000s)	Route Designators	Route Residuals (000s)	Host County	Hosting Residual (000s)
129	Kings	GPA	29.3	464.1	H-60/H-82	271.7/246.1	Susquehanna,PA	X
130	Kings	GPA	118.6	345.5	H-70/H-32	628.0/216.9	Fulton	144.6
131	Queens	GPA	87.4	519.3	H-50	X	Chenango	144.4
132	Queens	GPA	114.8	404.5	H-30/H-32	891.8/102.1	Fulton	29.8
133	New York	GPA	29.8	129.1	H-30/H-32	862.0/72.3	Fulton	X
134	New York	GPA	23.1	106.0	H-40	139.3	Chenango	121.3
135	Bronx	GPA	88.5	177.2	H-70/H-71	539.5/296.3	Warren	158.5
136	Westchester	GPA	99.2	198.6	H-30/H-71	762.8/197.1	Warren	59.3
137	Rockland	GPA	27.9	55.7	H-90	142.8	Tioga, NY	204.7
138	Richmond	GPA	37.9	37.7	H-90	104.9	Tioga, NY	166.8
139	Suffolk	GPA	59.3	256.9	H-70/H-71	480.2/137.8	Warren	X
140	Suffolk	GPA	98.8	158.1	H-90	6.1	Tioga, NY	68.0
141	Nassau	GPA	6.1	413.3	H-90	X	Tioga, NY	61.9
142	Nassau	GPA	72.3	341.0	H-70/H-32	407.9/ X	Herkimer	200.8
143	Nassau	GPA	131.2	209.8	H-70/H-72	276.7/452.2	Herkimer	69.6
144	Kings	GPA	121.3	224.2	H-40	18.0	Chenango	X
145	Kings	GPA	51.5	172.7	H-60/H-82	220.2/194.6	Bradford, PA	195.1
146	Queens	GPA	69.6	334.9	H-70/H-72	207.1/382.6	Herkimer	X
147	Queens	GPA	132.6	202.3	H-60/H-82	87.6/62.0	Bradford, PA	62.5
148	New York	GPA	52.9	53.1	H-60/H-82	34.7/ 9.1	Bradford, PA	9.6
149	Bronx	GPA	9.1	168.1	H-60/H-82	25.6/ X	Bradford, PA	0.5
150	Bronx	GPA	25.6	142.5	H-60/H-81	X /289.9	Tioga, NY	36.3
151	Bronx	GPA	36.3	106.2	H-80/H-81	206.6/253.6	Tioga, NY	X
152	Bronx	GPA	17.5	88.7	H-70/H-72	189.6/365.1	Oneida	4.0
153	Westchester	GPA	18.0	180.6	H-40	X	Cortland	211.5
154	Westchester	GPA	81.2	99.4	H-80/H-81	125.4/172.4	Cortland	130.3
155	Rockland	GPA	4.0	51.7	H-70/H-72	185.6/361.1	Oneida	X
156	Rockland	GPA	23.9	27.8	H-70/H-81	161.7/148.5	Cortland	106.4
157	Richmond	GPA	37.7	X	H-80/H-81	87.7/110.8	Cortland	68.7
158	Suffolk	GPA	68.7	89.4	H-80/H-81	19.0/ 42.1	Cortland	X
159	Suffolk	GPA	19.0	70.4	H-80/H-81	X / 23.1	Tompkins	230.3
160	Suffolk	GPA	23.1	47.3	H-70/H-81	138.6/ X	Tompkins	207.2
161	Suffolk	GPA	47.3	X	H-70/H-31	91.3/380.3	Madison	90.5
162	Nassau	GPA	63.5	146.3	H-70/H-31	27.8/316.8	Madison	27.0

Table 18 (Concluded)

Move	Risk County	Population Group	Number Moved (000s)	Group Residual (000s)	Route Designators	Route Residuals (000s)	Host County	Hosting Residual (000s)
163	Nassau	GPA	27.0	119.3	H-30/H-31	735.8/289.8	Madison	X
164	Nassau	GPA	23.6	95.7	H-30/H-71	712.2/114.2	Hamilton	X
165	Nassau	GPA	95.7	X	H-30/H-72	616.5/265.4	Lewis	22.5
166	Kings	GPA	22.5	150.2	H-30/H-72	594.0/242.9	Lewis	X
167	Kings	GPA	132.2	18.0	H-30/H-72	461.8/110.7	Oswego	X
168	Kings	GPA	18.0	X	H-30/H-72	443.8/ 92.7	Jefferson	424.5
169	Queens	GPA	202.3	X	H-30/H-31	241.5/ 87.5	Tompkins	4.9
170	New York	GPA	4.9	48.2	H-30/H-31	236.6/ 82.6	Tompkins	X
171	New York	GPA	48.2	X	H-30/H-72	188.4/ 44.5	Jefferson	376.3
172	Bronx	GPA	44.5	44.2	H-30/H-72	143.9/ X	Jefferson	331.8
173	Bronx	GPA	44.2	X	H-30/H-71	99.7/ 70.0	Jefferson	287.6
174	Westchester	GPA	70.0	29.4	H-30/H-71	29.7/ X	Jefferson	217.6
175	Westchester	GPA	29.4	X	H-30/H-31	0.3/ 53.2	Jefferson	188.2
176	Rockland	GPA	27.8	X	H-70/H-31	X / 25.4	Jefferson	160.4
			* * * * * * * * * * * * * * * * * * * *					
177	Albany	GPB	47.3	X	NY7/I88	Bus and Truck	Chemung	417.2
178	Schenectady	GPB	19.5	X	""	"	Chemung	397.7
179	Albany	GPA	176.0	X	"	183.1	Chemung	221.7
180	Rensselaer	GPA	9.6	X	"	173.5	Chemung	212.1
181	Schenectady	GPA	106.3	X	"	67.2	Chemung	105.8
182	Onandaga	GPB	63.2	X	I81	Bus and Truck	Jefferson	97.2
183	Onandaga	GPA	97.2	217.9	I81	N/A	Jefferson	X
184	Onandaga	GPA	175.4	42.5	H-72	"	Seneca	X
185	Onandaga	GPA	42.5	X	H-72	"	Ontario	351.7
186	Monroe	GPA	229.1	X	Local	"	Livingston	41.1
187	Erie	GPA	344.3	X	Local	"	Cattaraugus	64.0

route or completing the allocation of the population group. To speed the analysis process, more than one special highway route to a host county was sometimes used in a single move in private autos if the capacity of one highway route was exhausted in the process. Preparation of a move table is time consuming and detailed--for example, 187 moves were made in the base solution.

A subsidiary analytical tool was an allocation sheet that consisted of four columns for each risk county (one for each population group) and lines for each host county, together with its hosting capacity. As the move table indicated that the hosting capacity of a county had been used up, the moves to that point were entered into the allocation table and the assignments summed along the host county line to determine a proof total. Similarly, when a risk county population group was completely assigned, the appropriate column was summed to establish a proof total as a check on the calculation.

In the allocation of groups relocating by auto, a mileage table between the New York risk counties and the candidate host counties was used to select the closest available host county. The mileages were along the actual route to the approximate centroid of each county. If a particular host county could be reached by means of several routes, the mileages for each route were shown. Some of the special highway routes were necessarily circuitous to achieve the highest capacity. Hence, a substantial difference in distance could be involved, depending upon what route capacities remained available at the time of a given move.

The move table for the base solution is shown in Table 18. The conditions affecting this allocation are that nonhighway modes and buses move persons without autos within three days. The production of highway routes for first autos is based on operations for 3.3 days. This is the shortest time estimate obtained from a series of trial. In other words, autos continue to exit the New York metropolitan area for about 7 hours beyond the three-day period. It is not possible to balance loads and capacities perfectly on all routes. Hence, one would expect operation to run for longer or shorter times on the various highway routes.

In Table 18, the move numbers are in the left-hand column. In Move 1, the available hosting space within Suffolk County is allocated to essential workers and their dependents with autos (EWAs). The space available, 148,000, is not enough for all EWAs, so there is a residual of 49,400 still to be served. Because the Suffolk County host capacity has been exhausted, the right-hand column receives an X. In Moves 2 through 5, all EWs in Westchester and Rockland Counties are assigned hosting space within these counties, with space remaining for EWs from other risk counties.

At Move 6, the allocation of airlift begins with emphasis on those routes that can be used for commuting. Suffolk County is so located as to require the most difficult ground commuting. Therefore, the allocation begins at a Suffolk County Airport (see Route A-13 of Table 14). The daily commuting capacity is 5,400 persons. These essential workers and their dependents total 13,500 persons. This number of EWBs are assigned in Move 6 to go from Calverton to Elmira where they will be hosted in Chemung County. There are 14,700 EWBs in Suffolk County; hence, a group residual of 1.2 thousand is shown after the number moved. In the next column, the route designator, A-13, is shown, together with the remaining capacity on the route. Commuting capacity is exhausted. Therefore this capacity is assigned to Suffolk GPBs in Move 7. The fact that A-13 is filled is indicated by an X.

At Move 8, the remaining Suffolk EWBs are assigned to Route A-14. Since there is capacity for essential workers left on this route, the space (for 12,300 persons) could be assigned either to Nassau EWBs bused out-island to Westhampton or to Suffolk EWAs who could drive to the airport. The latter course is chosen in Move 9 to avoid the long ground commute by auto. By Move 13, all Suffolk County essential workers have been allocated to airlift. The remaining commuter routes are assigned to EWBs and GPBs from the counties most convenient to the risk-area airports. The capacity on all air routes is allocated by Move 37.

Beginning with Move 38, rail capacity is allocated, again emphasizing the relocation of EWBs. The capacities in Table 15 are used.

Most of the routes are completely allocated. The exceptions are the short routes ending in the risk-area; R-1a and R-1b are not fully used. Some residual capacity remains on R-2b after all EWBs have been allocated (Move 47). Those assigned to Route R-2b must be bused from North White Plains to host locations in Westchester and Putnam Counties. Since all EWBs have been assigned at this point, either EWAs must be required to use the short rail lines and buses or GPBs must be allowed to occupy the close-in hosting space in lieu of essential workers. Neither of these alternatives seemed advantageous; hence, Route R-2b was not used further.

The long-haul rail routes are allocated to GPBs in Moves 48 through 52. The host counties chosen--Steuben, Cayuga, and Tompkins--are at the outer border of the hosting area needed by persons from the New York metropolitan area.

Next, the remaining EWAs in the New York metropolitan area are allocated highway capacity to the closest available host counties. All Suffolk County EWAs and about one-third of the Richmond County EWAs have already been assigned to commuter air routes. Hence, the highway allocation begins with the remaining Richmond County EWAs, who are assigned to Rockland County via the Palisades Parkway leg of H-90, a distance of about 60 miles. The H-90 route residual shown is obtained by subtracting the assigned 32.1 thousand people of Move 53 from the route production estimate shown in Table 17. The remaining hosting capacity in Rockland County is assigned to Nassau County EWAs in the next move. There is a group residual of 142,300 persons.

At Move 55, the remaining Nassau County EWAs are assigned to Putnam County, which is next closest, about 68 miles. In this case, two routes are specified. In Table 17 the production estimate for H-10 is 49,100 lower in Dutchess County than it is in Putnam County. To use the route fully, this exact amount is assigned to H-10, making its residual precisely equal to the bottleneck capacity in Dutchess County. The remaining 93,200 Nassau County EWAs are assigned to H-80. The two values shown under the Route Residuals column are the remaining production on H-10 and H-80, respectively. All EWAs are assigned highway capacity by Move 60.

In Move 60 the Bronx EWAs number 110,700, whereas the production estimate in Table 17 for H-20 is 110,500. H-20 is the backhaul route, and this small differential in loading is not considered significant.

At this stage of the base solution, all EWs in the New York metropolitan area have been allocated to transportation routes and host counties. For those who will commute by auto, the maximum distance is about 80 miles. There remain a large number of GPBs in the area that must be provided with transportation. Some of these can go by water up the Hudson River, but most must be transported by bus or truck. Because potential destinations for some of these people could interact with the allocation of hosting space in the outlying risk areas (Table 13), the next step in the base solution is to establish hosting space for all essential workers and dependents in these areas. This is done in Moves 61 through 80, using the policy rule that outlying risk counties have priority for hosting space within their boundaries. Thus, for example, all but 9,600 GPAs are hosted within Rensselaer County. In no case are other than EWs assigned to a neighboring county at this point.

In Moves 81 through 86, the water production estimates discussed in Section V are allocated to GPBs in New York County (Manhattan), where 78% of people are without automobiles. Those destined for ports in the Albany-Troy area would be bused to Saratoga County.

Next, the remaining GPBs are allocated to buses. The assignment is in approximate order of distance from hosting space along the New York Thruway (H-70 and H-72). Orange, Ulster, and Greene Counties are filled in succession. The final groups are relocated to Montgomery County, just beyond Albany, a distance of approximately 200 miles. These steps are complete at Move 96. The total number of people moved along H-70 by bus turned out to be 1,758,500. At 50 persons per bus, 35,170 busloads would be required over the three-day period. Assuming 20 hours as the effective day, there would be 586 buses each hour, each displacing two autos that otherwise might use the highway. Capacity for about 218,000 persons in autos would be displaced because of the bus traffic. In Table 17, the 3.3-day auto production estimate for H-70 has been reduced by this amount, and the net production is shown in parentheses. It is

this net amount that has been used in allocating autos to H-70. In a similar way, the bus traffic beyond Greene County has been used to obtain a net production estimate for H-72.

Allocation of GPAs in the New York metropolitan area to the remaining highways starts at Move 97, beginning with Richmond County (Staten Island) and ending with Rockland County in each 20-percent slice iteration. Note, for example, that the Richmond group residual is four times the number moved in Move 97; that is, 20% are moved and 80% remain to be moved. The first iteration places people in Dutchess and Columbia Counties east of the Hudson River and in Sullivan and Delaware Counties to the northwest. The road distances range from 107 miles to 143 miles. At Move 98, the route residual for H-80 is reduced to 441,300 people, which is somewhat below the bottleneck capacity of the narrow bridge over the Hudson (H-81, Table 17). Thereafter, H-80 is used only to feed traffic to H-81 and H-82 on the west side of the river.

Route H-81 (NY 52) joins H-90 in the western part of Sullivan County. Since Orange and Ulster Counties have been filled by buses, and H-90 itself is the more direct route to Sullivan and Delaware Counties, H-81 will be used mainly as a feeder to H-90. The number of people allocated to hosting via H-90 prior to the H-81 interchange is 414,700 (Moves 53, 54, 104, 105, and 106). Hence, the production of route H-81 is reduced to this amount in Table 17 so as to just replace the depleted stream on H-90. Because of this adjustment, it is not necessary to further deplete the H-90 residual when H-81 is specified.

The second 20-percent slice iteration begins at Move 110 and is completed at Move 123. The road distances range from 157 miles (Richmond to Delaware) to 196 miles (Bronx to Broome). At Move 112, H-60 is first used as a feeder to H-82. H-60 only traverses Rockland and Orange Counties, both of which were filled earlier. H-60 is, however, an invaluable route as its production, along with that of H-80 over the Hudson River bridge, is about in balance with H-81 and H-82.

The third 20-percent slice iteration begins at Move 124 and is completed at Move 137. Road distances for this group range from 195 miles (Rockland to Tioga, New York) to 235 miles (New York to Chenango). At this stage, H-10, H-20, and H-50 have been fully allocated.

The fourth 20-percent slice iteration begins at Move 138 and is completed at Move 156. Routes to the nearby counties along the Pennsylvania border are exhausted during this iteration and the allocation is moved to the north. H-90 is used up at Move 141, H-82 at Move 149, and H-40 at Move 153. Road distances range from 222 miles (Bronx to Tioga, New York) to 260 miles (Kings to Chenango). Thus, about 80% of first autos can relocate within the range of a tankful of gasoline.

The final 20-percent slice iteration begins at Move 157 and is completed at Move 176. After the production of H-81 is exhausted at Move 160, all allocations must be made to the north via H-70 and H-30, the only two remaining outbound highways. Since H-30 (the Taconic State Parkway) is east of the Hudson, only H-70 is available to Rockland County. Hence, capacity is reserved for Rockland at Move 162; that is, the number of Nassau GPAs assigned to H-70 is limited by this requirement. In subsequent moves, H-30 is used exclusively until Rockland's final turn.

In the base solution the capacities of the highways are almost completely utilized. The only excess production is for 300 people on H-30 leading from New York City and for 25,400 on H-31 west of Albany. This causes some difficulty in the final moves of the allocation (Moves 177 through 187) in which the general public in the outlying risk areas is allocated hosting space. Syracuse (Onandaga County) can be readily moved up I 81 to Jefferson County and west on the thruway since the New York traffic is greatly depleted. But the main arterials in the Albany-Schenectady-Troy area have been committed to New York City traffic. Moreover, there is insufficient hosting space to the north. It was therefore necessary to investigate a route to the southwest that would permit residents of the Albany area to travel beyond Binghamton to Chemung County without interfering with the New York exodus. The route chosen was I 88, which, though incomplete, has ample capacity to meet the need. The distance is about 215 miles.

Maximum relocation distances occur during the final iteration of the New York movement. These range from 276 miles (Richmond to Cortland) to 389 miles (Bronx to Jefferson). The maximum travel distances for the example allocation are shown in Table 19.

Table 19

MAXIMUM TRAVEL DISTANCES

Risk County	Maximum Travel Distance
Suffolk	307
Nassau	345
Kings	371
Queens	367
Richmond	276
New York	364
Bronx	389
Westchester	385
Rockland	287

Richmond County has the smallest distance, apparently by virtue of its lead position in the allocation order. The Bronx has the greatest travel distance, about 40% farther than Suffolk. The average travel distance for autos from Richmond County was found to be 197 miles; for the Bronx, 227 miles. For comparison, the maximum distance passengers are bused is 203 miles.

Summary

The principal results of the base solution are as follows:

- 11.33 million people are relocated in 3.3 days.
- All persons without access to a first auto are relocated in three days.
- Only 532,000 persons remain in the risk area at the end of the third day. All have first autos and are awaiting availability of highway capacity.
- More than 900,000 essential workers are transported both ways between host areas and jobs each day.

Estimates of resources needed for the "trunk-line" or main relocation movements are as follows:

- Highway
  - 25 highway lanes
  - 2.0 million autos
  - 5,000 buses
- Rail
  - 7 rail routes
  - 1,700 passenger cars
  - 3,600 freight cars
  - 540 locomotives
- Air
  - 7 risk airports
  - 14 host airports
  - 273 commercial aircraft
- Water
  - Hudson River Waterway
  - Port facilities
  - Ocean vessels, ferries and small passenger vessels, tugs and barges, fishing boats and pleasure craft.

In addition, many streets, roads, and vehicles of all types are used for local "feeder and distribution" services in the risk and host areas.

The resources most fully utilized and most essential for success are highway lanes, rail routes, and host area airports. Most other resource classes were less critical to success and most were not fully utilized.

Table 20 summarizes the numbers of persons relocated, by class and mode of travel; the numbers of essential workers transported to and from jobs, by mode of travel; and the duration of relocation operations by each mode.

Deficiencies

The base solution is deficient in a number of ways.

- The three-day evacuation target for the New York metropolitan area was not met--the last auto departs the risk area about 3.3 days after initiation of the movement.

- Relocation of the population at risk in the New York metropolitan area stresses the available highway capacity to such a degree that the evacuation of the Albany-Schenectady-Troy risk area is constrained to one evacuation route to the southwest.
- About 20% of first autos must travel over 250 miles, thus introducing a refueling requirement.
- Some counties relatively close to New York City are not used for hosting, while people are transported to more distant counties. Steuben County, for example, is not used because of limited highway capacity, although it is 100 miles nearer the city than Jefferson County, which is used.
- Available highways to the east and south of New York are not used because hosting in those areas is denied under current DCPA policy.
- A large fraction of the bus and large truck inventory is not used.

Table 20

SUMMARY OF BASE SOLUTION

Transportation Mode	Duration (Days)	Total	Persons Transported (000) General Public	Essential Workers and Dependents	Essential Workers
Nonhighway					
Air	3.0	1,216.8	978.3	238.5	95.4
Rail	3.0	1,531.0	780.0	751.0	300.4
Water	3.0	300.0	300.0	--	--
All nonhighway	3.0	3,047.8	2,058.3	989.5	395.8
Highway					
Bus	3.0	1,758.5	1,758.5	--	--
All nonauto		4,806.3	3,816.8	989.5	395.8
First auto	0-3.0	5,652.8	4,713.0	939.8	375.9
	3.0-3.3	532.0	532.0	--	--
All first auto		6,184.8	5,245.0	939.8	375.9
All modes		10,991.1	9,062.0	1,929.2	771.7
Within home county		336.4	--	336.4	134.6
Total population at risk		11,327.5	9,062.0	2,265.5	906.2

Note: Totals may not add due to rounding.

VIII ALTERNATIVE SOLUTIONS

It is quite possible that those responsible for crisis relocation planning will consider a relocation operation of 3.3 days duration to be entirely acceptable as a solution to the problem of evacuating the New York metropolitan area. However, it can also be argued that the three-day target should be met--as a minimum--and surpassed, if possible, simply as a measure of prudence and safety. Therefore, alternative solutions of various kinds have been examined.

The objective of this section is to explore means of shortening relocation time, and to alleviate or eliminate other deficiencies of the base solution. Eleven alternatives have been formulated and subjected to evaluation. Results are stated below. Each alternative incorporates one or more changes in the definition of the problem or the conditions used in the base solution described in Section VII.

Changes considered depend upon the deficiency to be corrected. The following changes were considered:

- Deny some travelers use of their first autos and increase the use of large vehicles, to the extent needed, to ensure completion of relocation in three days (see Alternatives 1 and 2).
- Extend the duration of operation of the nonhighway modes just enough to balance the durations of movements via first autos and are other transportation modes (see Alternative 3).
- Assign buses to more distant hosting areas and reserve closer counties for first autos to shorten auto trip lengths (see Alternative 4).
- Reassign buses to H-90 and a supplemental route in New Jersey, rather than to H-70 (see Alternative 5).
- Use hosting ratios higher than 5 to 1 in counties just north of New York City (see Alternative 6).
- Revise the boundaries of the New York planning area to regain Washington County, New York, from the New England planning area (see Alternative 7).

- Obtain the right to use two freeway lanes in New Jersey--H-100 (see Alternative 8).
- Increase hosting capacity near New York City by revising hosting criteria or making provisions for expedient shelter. Areas of special interest are in certain parts of Suffolk County, New York, and Monmouth and Ocean Counties, New Jersey (see Alternative 9).
- Increase average passenger loads of first autos (see Alternative 10).
- Plan for spontaneous evacuation and refusal to relocate (see Alternative 11).

The detailed move table procedure described in Section VII has not been applied in the analysis of alternatives. Instead, the results of the base solution were used as a point of departure for "shortcut" calculation of the effect of alternative conditions upon total relocation time and certain other characteristics of relocation operations. The results of these shortcut methods do not reflect all interactions that might occur and are not sufficiently detailed for final evaluation of alternatives or as the basis for planning.

Alternative 1

Alternative 1 assumes that the three-day goal will be met by requiring some people who have access to first autos to leave their cars behind. They would be transported in buses to increase production of the highway system. Relocation by air, rail, and water would remain the same as in the base solution.

Estimating the number of buses to be exchanged for autos requires several steps. It was shown above that the highway system in the base solution moved 187,500 persons by first auto each 0.1 day. To reduce the duration from 3.3 days to 3.0 days would first require getting 562,500 people out of first autos and into buses. This will make 11,250 busloads. Adding 11,250 bus trips to the highway will displace 22,500 first autos and 69,750 persons. These new bus passengers will from 1,395 bus loads and will displace an additional 2,790 autos and 8,650 persons. The new increment of passengers makes up 173 busloads. A few more steps of this chain are needed to end the exchange of autos for buses. At the end of the chain, it was found that about 642 thousand persons must be denied use of first autos and transported by buses.

This alternative achieves the three-day goal, but it may be argued that it would be difficult for planners to decide which persons should be denied use of their autos. Also it must be assumed that households possessing an auto will want to use it, and planners therefore would have to devise enforcement schemes. Even then, obtaining cooperation of the general public is likely to be difficult.

Alternative 2

Alternative 2 also assumes denial of use of a significant number of first autos. However, in this alternative, buses are used to relocate essential workers and their dependents who have access to a first auto rather than members of the general public. In comparison with Alternative 1, this alternative may be easier to plan and manage and may be more acceptable to the public.

The alternative has additional advantages that might recommend it in the absence of the problem of selecting people to travel via bus, as in Alternative 1. In the base solution some households possessing an automobile were assigned to air transport rather than to their first automobiles. These were essential workers and their dependents in Suffolk and Richmond Counties. It was argued that these assignments were preferable to the daily ground commuting that would otherwise be in prospect. Our suggestion is that all essential workers and their dependents be transported to their nearby host counties by air, rail, and bus modes. One advantage of the use of more buses would be to simplify and ease the commuting problem. Another advantage would be to ease the control of access into counties reserved for essential workers--no first autos would be permitted off certain exit ramps. In the base solution, 939,800 EWAs--including 376,000 essential workers--traveled by auto. This is more than the 642,000 who would be denied use of the first autos and transported by bus in Alternative 1 to achieve a three-day movement period.

In Moves 54 through 60 of Table 18, most EWAs are assigned to Putnam and Dutchess Counties. With this allocation, bus transport

would be needed on both H-80 and H-70. A return route would be needed for buses on H-80. In the base solution, H-20 is utilized as the central backhaul route on the east side of the Hudson River. In Alternative 2 it may be advantageous to use H-20 entirely for the return of buses.

The increased number of EWAs traveling by bus in Alternative 2 exceeds the number of persons shifted from auto to bus in Alternative 1 by almost 50%. The difference would be realized as a margin of surplus capacity for autos. Therefore, adoption of a policy of requiring all EWAs to relocate by nonauto modes would achieve the goal of a three-day movement period and would also ensure a margin of safety or excess capacity that would considerably increase flexibility in planning the utilization of the highway system.

Alternative 3

Alternative 3 continues the movement of carless persons beyond three days and shortens the duration of first-auto movement until the operations are equal in duration. In the base solution, the nonhighway modes moved 3,047,800 persons in three days or 101,600 persons per 0.1 day of operation. If the nonhighway modes were operated, for example, for an additional 0.1 day, 101,600 people could be shifted out of buses on H-70. At 50 persons per bus, there would be 2,032 less bus trips needed. Since two autos may be substituted for a bus, 4,064 first autos and 12,600 persons could be added during the first three days. (The base solution assumes that H-70 is used solely by autos after three days.) Thus, capacity for about 12,690 persons is added to the highway systems for each additional 0.1 day of operation by the non-highway modes. On the other hand, the highway system in the base solution moves 6,185,800 persons in 3.3 days, or about 187,500 persons per 0.1 day. It can easily be seen that operation of the nonhighway modes and buses for 3.3 rather than 3.0 days would reduce the duration of the first-auto movement by a negligible amount. A major reason is that autos of low carrying capacity are being substituted for highly productive buses.

Alternative 4

Alternative 4 changes the destinations of passengers being bused on H-70 (and its continuation, H-72) from relatively near host counties to more distant host counties and makes complemental changes in destinations of first autos. The base solution places these bus passengers in the closest available space in counties traversed by the bus route; hence, they are hosted in Orange, Ulster, Greene, and Montgomery Counties (Table 18, Moves 87 through 96). The number of persons transported by bus, 1,758,500, is nearly 30% as great as the 6,185,800 persons traveling by first auto.

Under Alternative 4, 20% of the GPAs, who are required to travel more than 250 miles via auto in the base solution, are reassigned to close areas--Orange, Ulster, and Greene Counties. The bus passengers displaced from those close areas are sent to distant counties.

The 3.3-day production of route H-70 for first autos is 1,009,500 persons (see Table 17). This number of people could be hosted in Orange County and part of Ulster County. The remainder of Ulster County and Greene County could only be filled by first autos traveling via H-40 and H-50, or by having H-30 travelers double back from the Albany area. Experience in the trials leading to the base solution suggests that H-40 and H-50 should be used to provide access to the next counties to the west. Doubling back from Albany would be complicated and inefficient. Hence, the first assignment of buses should fill the remainder of Ulster County and proceed outward along H-70 and H-72. If this were done, buses would reach as far as Ontario County on H-72.

In the base solution the average travel distance via bus is 102 miles. In Alternative 4 the average distance by bus would be 236 miles (see Table 12). About 4,880 buses are required in the base solution, while about 11,000 buses would be required in Alternative 4 because of the longer trip. This increase in buses employed is not critical--Section VI indicates that about 20,000 buses are available. Since buses will be traveling as far as 370 miles, bus refueling, probably in the Utica-Rome area, would be necessary. This is a smaller problem than auto refueling and should be manageable.

In Alternative 4 the number of persons in autos reassigned to Orange and Ulster Counties is about 40,000 persons short of the number that would be needed to ensure that no first autos travel more than 250 miles. This 250-mile maximum travel goal could be achieved by a further minor adjustment of the bus assignments to assign travelers via H-30 to hosting space in Montogomery or Herkimer Counties.

A bus carrying 50 people displaces two first autos, each assumed to carry 3.1 persons. Therefore, buses are more than eight times as efficient as first autos in the use of highway capacity. It is for this reason that all of the persons traveling via auto on H-70 can be hosted in Orange and Ulster Counties. This reduces the traffic on H-70 and H-72 in the Albany area and should alleviate or eliminate the difficulties experienced in the base case in the evacuation of the Albany-Schenectady-Troy risk populations. In Alternative 4 these people would be able to travel via highways to the west and north.

Alternative 5

Alternative 5 considers the redirecting of some or all of the bus traffic from route H-70 to route H-90. It will be recalled from Section VII that one of the lessons of the base solution was that highway production for first autos in the direction of Binghamton is so limited that desirable hosting counties relatively close to the New York metropolitan area, such as Steuben County, cannot be used. Because buses are much more efficient than autos, a good rule to thumb for planners might be to use buses on those routes where limited highway production tends to deny use of large hosting capacity near the risk area. In the base solution, 1,758,500 persons are transported by bus on H-70 at the cost of displacing only 218,100 persons that would have traveled by first auto. H-70 and most of H-90 are limited access highways with capacities of 750 buses per hour per lane. Thus, the question arises as to whether it would not be a good idea to send the buses on H-90 rather than H-70, thus providing ample hosting space for first-auto travelers to the north and shortening bus travel by use of counties to the west of Binghamton.

The main difficulty of Alternative 5 is that buses must make round trips--over 35,000 bus trips are required and only about 20,000 buses are available. Therefore, a backhaul route would be essential. The problem differs from the base solution. Route H-70 has six lanes to Albany; in the base solution, four lanes are used outbound, a fifth lane is used as a buffer, and the sixth lane is used for backhaul. Route H-90 is only four lanes and in the base solution all are used for outbound traffic. Making H-90 a two-way route with two lanes for autos and buses outbound and two lanes for buses returning would greatly reduce its overall production for first autos and thus defeat the purpose.

One way around the difficulty would be to employ all 20,000 buses plus 15,000 large trucks and semitrailers so that round trips would be unnecessary. A second scheme would be to obtain a new highway route not used in the base solution. This hypothetical route is called H-100--however, it has not been defined in detail. H-100 would have to pass through northern New Jersey into the four Pennsylvania counties and to the southern tier of New York counties. Brief analysis of the New Jersey and Pennsylvania highway networks indicates that highways exist that have more than enough capacity to satisfy the bus backhaul needs of the New York risk area--about 600 vehicles per hour. Of course, H-100 would only be available if planned cooperatively by New York and New Jersey. The addition of H-100 to the New York highway system for relocation travel would expand the capacity of the system, thus shortening the movement period to some extent. (This aspect is discussed again under Alternative 8.)

Alternative 6

Alternative 6 assumes that additional hosting capacity is generated, in the near counties north and west of New York City, by increasing hosting ratios above 5 to 1. It was suggested in the feasibility study that it might be advantageous to increase the hosting ratio in those counties having a prospective lower-than-average fallout risk and to reduce it in counties at higher risk. Alternatively the increase might be justified by a program for expedient shelter in those counties.

The counties between New York and Albany have low expected fallout levels. The feasibility study suggested that such counties might have their hosting capacity increased by 50%--to 7.5 to 1. However, an increase of 30%--to 6.5 to 1--in Westchester, Rockland, Putnam, Orange, Dutchess, Sullivan, Ulster, Greene, and Columbia Counties would be sufficient to avoid any first-auto travel beyond 250 miles. This assumes no change in the assignment of buses from the base solution. Again, this alternative does not affect the duration of the relocation movement.

Alternative 7

Alternative 7 considers a change in the New York planning area boundaries by regaining the use of Washington County, New York, which was assigned to the New England planning area in the feasibility study (see Figure 1). Washington County has a hosting capacity for 263,600 people at a 5-to-1 hosting ratio and is about 200 miles from the New York area via H-10 and H-30. The county does not have enough capacity by itself to give major relief for the maximum travel distances found in the base solution for the New York metropolitan area. For example, in moves 172 and 173 of Table 18, the movement of people from the Bronx to Jefferson County by a somewhat circuitous route might be avoided (389 miles), but distances of about 370 miles would remain.

On the other hand, Washington County is convenient to the Albany-Schenectady-Troy area, and its availability would considerably relieve the relocation problem for that area. The loss of Washington County to the New England planning area would not be highly significant. New England does not use all available hosting capacity and enjoys shorter travel distances than the New York risk area. Therefore, New England's sacrifice does not appear severe. The change of boundaries would shorten travel distances, but it does not add to the highway capacity in critical areas. Consequently, no reduction in the duration of the movement period would result.

Alternative 8

Alternative 8 assumes that an additional highway, the hypothetical H-100 referred to earlier, can be borrowed from New Jersey to add capacity for the New York population. As noted before, additional capacity for 562,500 persons in first autos would be needed. If the highway route can be obtained, its use will allow access to the desirable hosting area west of Binghamton, and travel to the most distant counties will be avoided. To accommodate the required number of autos and persons, H-100 would have to provide the equivalent of 2.1 freeway lanes to New York. A brief review of the New Jersey highway system indicates that highways with the necessary capacity exist. However, since the relocation needs of the risk population in northeastern New Jersey must also be served, joint analysis of the relocation problems of the New York and New Jersey area would be needed to determine whether Alternative 8 is feasible. If so, it will provide the same advantage as Alternative 4: relocation in three days and utilization of all first autos.

Alternative 9

Alternative 9 also achieves a movement period of three days or less for New York City. It requires either a change in policy regarding hosting criteria to permit the hosting of relocatees in areas potentially subject to high fallout levels, or a program to provide expedient fallout shelters in those areas. This possibility is discussed thoroughly in the feasibility study. Whether based on an assessment of the likelihood of a mostly-surface-burst war or on plans to produce high-quality fallout shelters for both residents and relocatees, the opening up of so-called "green" counties to hosting makes a great difference in the New York relocation problem. The candidate areas considered for hosting in Alternative 9 are parts of Suffolk County and Monmouth and Ocean Counties in New Jersey.

As stated above, 562,500 persons and 181,450 autos are unable to depart the risk area by the end of the third day in the base solution.

In alternative 9 these persons would travel via auto to the new hosting area. Approximately 180,000 would remain in Suffolk County, assuming a 5-to-1 hosting ratio. About 382,500 persons and 123,400 autos would travel south via the Garden State Parkway. Only 1.3 freeway lanes are needed and the parkway has more than ample capacity.

Monmouth and Ocean Counties have a potential capacity of over one million relocatees, at 5-to-1. Only a part of the capacity would be needed to solve New York's most pressing problem. Of course, if a decision were made to allow hosting in the New Jersey green counties, it would be great advantage to northeastern New Jersey, as well as to New York, and a coordinated crisis relocation plan for the whole area would be needed.

Alternative 9 produces two attractive results: (1) all first autos can be used; and (2) the relocation operation would be completed within three days.

Alternative 10

Alternative 10 assumes that the average loads of first autos can be increased from 3.1 to 3.4 persons--that is, three extra riders per ten cars. If all of this increase were used to transport people with access to autos and to reduce the number of autos employed, relocation time would be shortened to 3.0 days.

Alternative 11

Alternative 11 assumes that 5% of the population having access to first autos locates spontaneously during the crisis buildup and that another 5% decline to relocate. This reduces the transportation burden via first auto by 10%. The effect would be to allow completion of the first-auto movement in 3.0 days. If 5% of the carless persons also relocated spontaneously and 5% declined to relocate, the duration of the nonauto relocation would be reduced to 2.7 days.

Appendix A

SPECIAL HIGHWAY ROUTES

Appendix A

SPECIAL HIGHWAY ROUTES

Tables A-1 through A-14 define the special highway routes used in this study and indicate bottleneck capacities and distances from the Bronx County line to the centroids of host counties.

Table A-1

ROUTE H-10

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos per Hour): One-way Outbound	Bottleneck Capacity (Autos per Hour): Two-way Unbalanced Flow	Distance from Bronx County Line to Centroid of Each County (Miles)
US 1	Westchester	> 2	> 2,340		
NY 120	Westchester	> 2	> 2,340		
NY 22	Westchester	> 2	> 2,340		32
NY 22	Putnam	2	2,340		46
NY 22	Dutchess	2	2,040		69
NY 22	Columbia	2	1,950	710	106
NY 22	Rensselaer	2		> 710	147
NY 22	Washington	2		> 710	189
NY 22	Essex	2		> 710	269

Table A-2

ROUTE H-20

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity	Distance from Bronx County Line to Centroid of Each County (Miles)
NY 22	Westchester			
NY 141	Westchester			
NY 120	Westchester			
NY 100	Westchester	> 2		33
NY 35	Westchester			
NY 118	Westchester			
US 6	Putnam			
NY 52	Putnam	2	800	47
NY 52	Dutchess	2	870	
NY 216 NY 52	Dutchess	2	> 800	
NY 55 + NY 376 NY 82	Dutchess	2	> 800	82
NY 82	Dutchess	2	> 800	
NY 82	Columbia	2	> 800	122

Note: Route H-20 is a utility route. It is a two-lane, two-way highway under normal usage. Flow is balanced in both directions.

Table A-3

Route H-30

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Bronx County Line to Centroid of Each County (Miles)
Sawmill River	Westchester	4	4,920	23
Taconic	Westchester	4	4,920	
Taconic	Putnam	4	4,920	42
Taconic	Dutchess	4	4,920	69
Taconic	Columbia	4	4,920	107
I 90	Columbia	4	6,000	
I 90	Rensselaer	4	6,000	150
I 90	Albany	4	6,000	165

Table A-4

Route H-31

Highway Number	County Name	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Albany to Centroid of Each County (Miles)
NY 85	Albany		
US 20	Albany	2,660	
US 20	Schenectady	> 2,660	14
US 20	Schoharie	> 2,660	26
US 20	Otsego	> 2,660	47
US 20	Herkimer	2,610	84
US 20	Oneida	> 2,610	106
US 20	Madison	> 2,610	118
US 20	Onondaga	> 2,610	143
US 20	Seneca	> 2,610	189
US 20	Ontario	> 2,610	214
US 20	Genesee	> 2,610	267
US 20	Erie	> 2,610	298

Table A-5

ROUTE H-32

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Albany to Centroid of Each County (Miles)
NY 443	Albany	> 2		
NY 5	Albany	> 2		
NY 5	Schenectady	2	2,770	14
NY 5	Montgomery	2	2,050	38
NY 5	Herkimer	2	> 2,050	72
NY 5	Oneida	2	> 2,050	102
NY 5	Madison	2	> 2,050	120
NY 5	Onandaga	2	> 2,050	143
NY 5	Cayuga	2	> 2,050	168

Table A-6

ROUTE H-40

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Bronx County Line to Centroid of Each County (Miles)
NY 100	Westchester			
NY 119	Westchester	> 2		
NY 9A	Westchester			
US 9	Westchester	4	Shares routes with H-50; no capacity problems anticipated	30
City street	Westchester	> 2		
US 9	Westchester			
US 9	Putnam	2	2,660	44
US 9	Dutchess			
NY 9E	Dutchess	> 2	> 2,660	
NY 376	Dutchess			77
US 9G	Dutchess			
US 9	Dutchess			
US 9	Columbia	2	> 2,660	89
NY 23	Columbia			
NY 23	Greene		> 2,660	
NY 23 + NY 145	Greene	2	> 2,660	109
NY 23 + NY 145	Delaware	2	> 2,660	168
NY 23 + NY 165	Otsego	2	> 2,660	192
NY 165				
NY 23 + NY 28	Chenango	2	> 2,660	234
NY 80				
NY 26				
NY 26 + NY 13	Chenango	2	> 2,660	
NY 26	Cortland	2	> 2,660	266

Table A-7

ROUTE H-50

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Bronx County Line to Centroid of Each County (Miles)
US 9	Westchester	> 2		33
NY 9D	Westchester			
NY 9D	Putnam	2	2,340	47
NY 9D	Dutchess	2	2,250	79
US 9	Dutchess			
US 9G	Dutchess			
NY 199	Dutchess			
NY 199	Ulster			
NY 55	Ulster	2	2,360	
NY 9W	Ulster			87
NY 28	Ulster			
NY 28	Delaware	2	> 2,250	158
NY 28	Otsego	2	2,260	
I 88	Otsego			
I 88	Chenango	> 2	> 2,260	208
I 88	Broome	> 2	> 2,260	
NY 434	Broome	> 2	> 2,260	234
NY 434	Broome		> 2,260	
NY 434 + NY 26 / NY 38B / NY 38 + NY 434	Tioga	> 2	> 2,260	
NY 96	Tioga	2	2,440	265
NY 224	Tioga	2	> 2,260	
NY 224	Chemung	2	> 2,260	280
NY 224	Schuyler	2	> 2,260	291
NY 14	Schuyler	2	> 2,260	
NY 14	Yates	2	> 2,260	314
NY 14	Ontario	2	> 2,260	331
NY 14	Wayne	2	2,020	347

Table A-8

Route H-60

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from George Washington Bridge to Centroid of Each County (Miles)
US 9W	(in New Jersey)			
US 9W NJ 502	(in New Jersey)			
US 9W + NJ 505	Rockland	> 2	2,550	
US 9W NJ 303	Rockland	2	> 2,550	36
US 9W	Orange	2		56

Table A-9

Route H-70

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr/Lane)	Distance from Bronx County Line to Centroid of Each County (Miles)
I 87	Bronx	6	1,500	
I 87	Westchester	6	1,500	13
I 87	Rockland	6	1,500	27
I 87	Orange	4	1,500	56
I 87	Ulster	4	1,500	84
I 87	Greene	4	1,500	121
I 87	Albany	4	1,500	150
Backhaul Route			Autos/Hr/Route	
US 9W	Albany	2	2,250	
US 9W	Greene	2	2,250	
US 9W	Ulster	2	2,360	
US 9W	Orange	2	2,540	
NY 32	Orange	2	2,540	

NOTE: H-70 is a mixed traffic route.

Table A-1G

ROUTE H-71

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr/Lane)	Distance from Bronx County Line to Centroid of Each County (Miles)
I 87	Saratoga	4	1,500	175
I 87	Warren	4	1,500	218
I 87	Essex	4	1,500	264
I 87	Clinton	4	1,500	304

Note: H-71 is a mixed traffic route.

Table A-11

ROUTE H-72

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr/Lane)	Distance from Bronx County Line to Centroid of Each County (Miles)
I 90	Albany	4	1,500	150
I 90	Schenectady	4	1,500	166
I 90	Montgomery	4	1,500	190
I 90	Herkimer	4	1,500	225
I 90	Oneida	4	1,500	251
I 90	Madison	4	1,500	272
I 90	Onondaga	4	1,500	295
I 90	Cayuga	4	1,500	318
I 90	Seneca	4	1,500	334
I 90	Ontario	4	1,500	356
I 90	Monroe	4	1,500	379
I 90	Genesee	4	1,500	411
I 90	Erie	4	1,500	436

Note: H-72 is a mixed traffic route.

Table A-12

ROUTES H-80 AND H-81

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Bronx County Line to Centroid of Each County (Miles)
H-80				
Hutchinson River Parkway (and I 95 + I 287)	Westchester	> 4	> 6,000	
I 684	Westchester	4	6,000	31
I 684	Putnam	4	6,000	45
I 84	Putnam	4	6,000	
I 84	Dutchess	4	6,000	57
Hudson River Bridge	Dutchess/Orange	2	2,770	
I 84	Orange	4	6,000	
Route H-81				76
NY 32 NY 84	Orange	2	2,700	
NY 32	Ulster			
US 44 + NY 52	Ulster	> 2	> 2,700	96
US 209	Ulster			
NY 55	Ulster			

Table A-13

ROUTE H-82

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from Bronx County Line to Centroid of Each County (Miles)
I 84 (H-83)	Orange	4	6,000	76
I 84 NY 97	Orange	4		
I 84 PA 37	Sussex, NJ	4	3,000	--
US 6 + PA 171	Pike, PA	2	3,000	
US 6 US 11	Wayne, PA	2	3,000	155
US 6	Lackawanna, PA	2	3,000	
PA 106	Lackawanna, PA	2	3,000	
PA 106	Susquehanna, PA	2	3,000	198
PA 706	Susquehanna, PA	2	3,000	
PA 706	Bradford, PA	2	2,000	253
US 6	Bradford, PA	2	2,000	
US 6	Tioga, PA	2	2,000	301

*Detailed information was not obtained for New Jersey and Pennsylvania roads.

Table A-14

ROUTE H-90

Highway Number	County Name	Number of Lanes at Bottleneck	Bottleneck Capacity (Autos/Hr One-Way Outbound)	Distance from George Washington Bridge to Centroid of Each County (Miles)
PIP* + I 80	Bergen, NJ	4	6,000	
PIP NJ 17	Rockland	4	6,000	36
PIP NY 17	Orange	4	6,000	62
US 6 + NY 210 NY 59	Orange	4	7,200	
NY 17	Orange	4	6,000	
NY 17	Sullivan	4	6,000	102
NY 17	Delaware	4	6,000	136
NY 17	Broome	4	6,000	189
NY 17	Tioga	4	6,000	215
NY 17	Chemung	4	6,000	254
NY 17	Steuben	4	6,000	285
NY 17	Allegany	4	6,000	333
NY 17	Cattarangus	4	6 000	384
NY 17	Chautauqua	4	6,000	431

*PIP = Palisades Interstate Parkway

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CRISIS RELOCATION OF THE POPULATION AT RISK IN THE NEW YORK METROPOLITAN AREA by Clark Henderson and Walmer E. Strope, Final Report, September 1978, SRI Project 5591, 136 pages, Contract No. DCPA01-76-C-0308, DCPA Work Unit 2313B, UNCLASSIFIED

The study treats the initial relocation of a risk population of 11.33 million persons and daily commuting by 0.91 million essential workers in the New York metropolitan area. A base case is described. Transportation resources are identified. Transportation capacity is estimated for air, water, rail, automobile, and bus transportation. Transportation operations and allocations of risk population groups to host areas are analyzed in trial solutions, and a base solution and move-table analysis are described. Relocation journeys are started by 95% of the population within 3.0 days and by the remainder at 3.3 days. Alternative cases treat changes in policies, conditions and constraints. Probable changes in duration of operations and transportation burdens are discussed. Substantial improvements over the base case appear possible.

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